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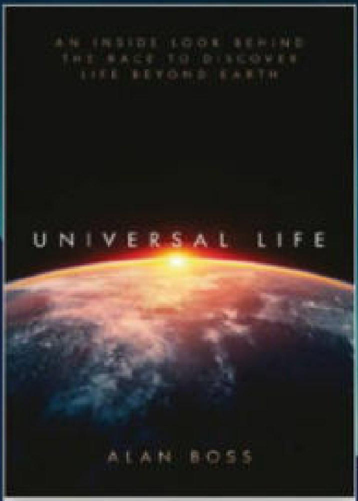
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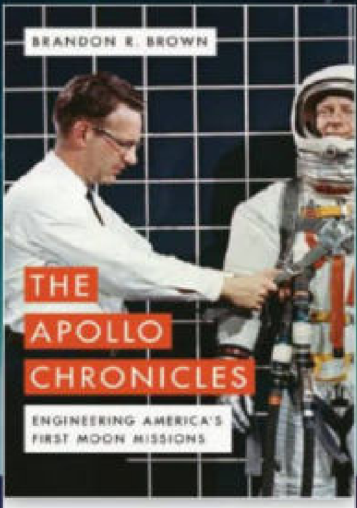

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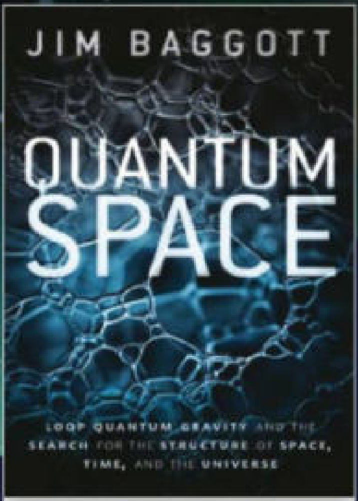
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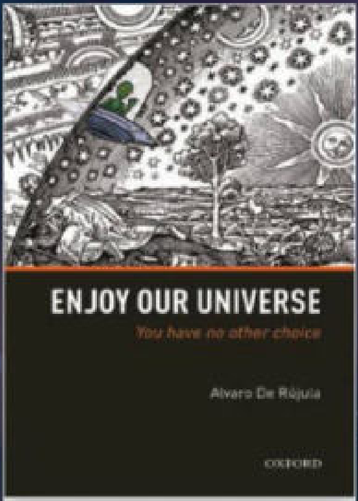

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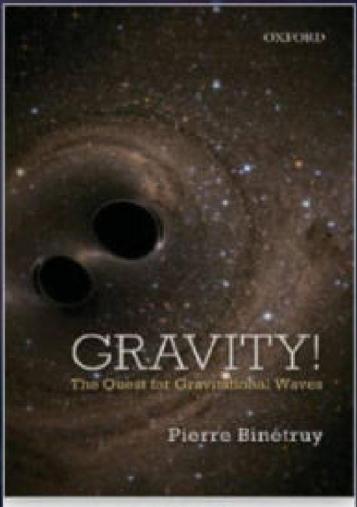

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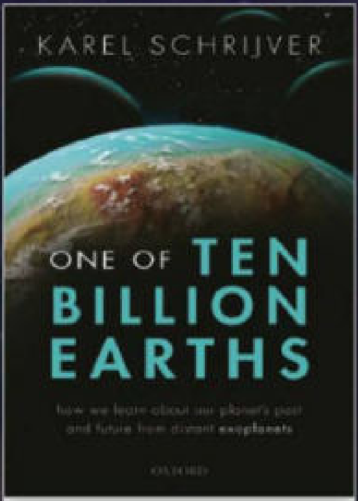
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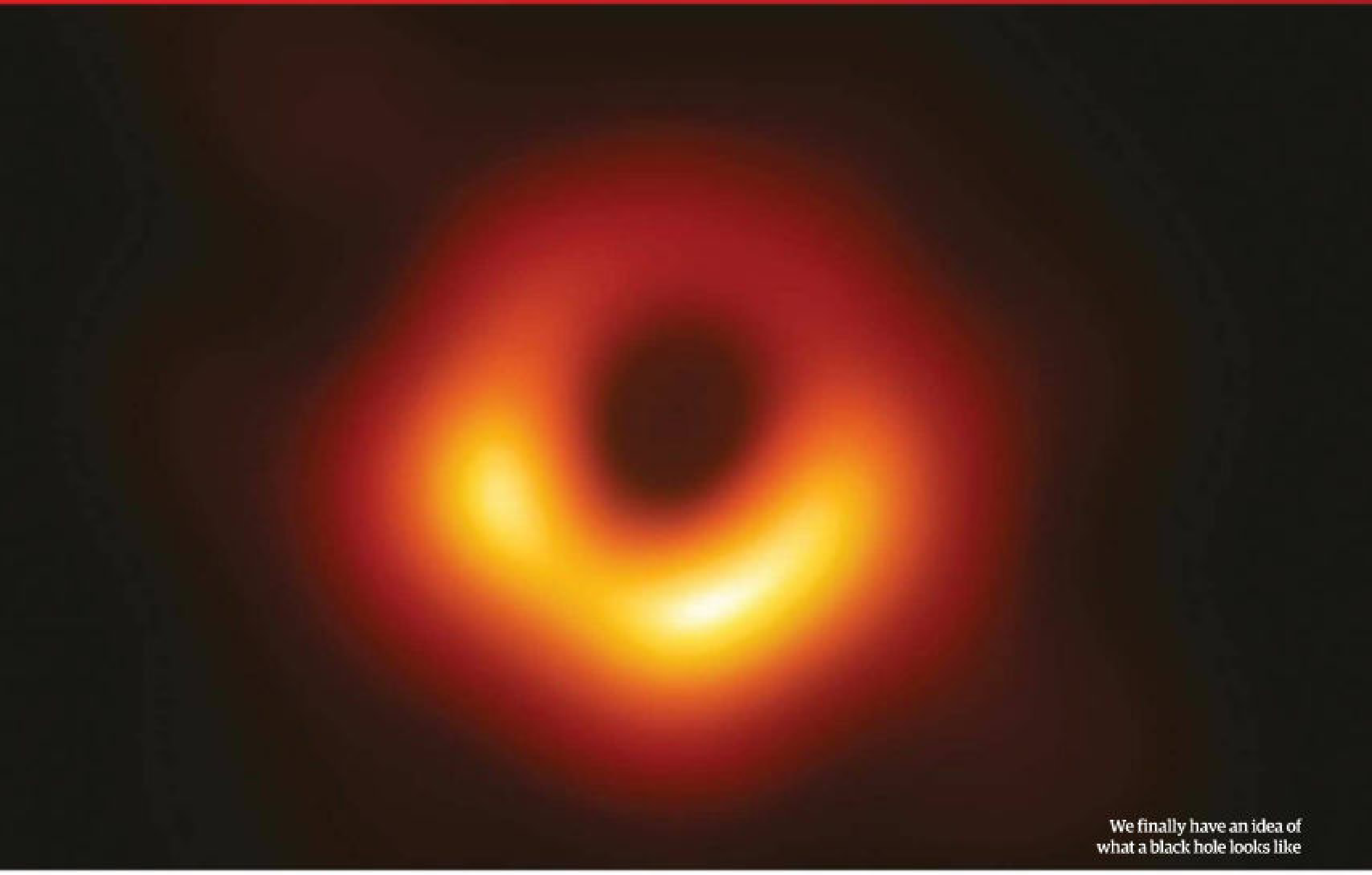

We finally have an idea of what a black hole looks like

© EHT Collaboration

Welcome

Somewhere on the edge of the confines of the Milky Way, there's suspected to be a small satellite galaxy. Sure, it's common for these galactic dwarfs to exist around the larger members of the universe's zoo of galaxies, but there's something particularly interesting about this one - we can't actually see it.

So what's the fuss? Astronomers suspect that it's there, but it's quite difficult to see - not least because we can't actually grab a bird's-eye view of our home galaxy, but because there's the added complication of it being almost devoid of stars. It's mostly comprised of dark matter, with a smidgen of interstellar gas fuelling a very small collection of glowing stars. The mysterious object goes by the name of Galaxy X.

This issue, you'll discover the astronomers who strongly suspect that it's out there - some 39,000 light years across - and they believe they have the proof: our very own galaxy seems to be acting quite strangely as a result.

Also this month, we caught up with Professor Brian Cox, who discusses not only his thoughts on climate change and the future of space exploration, but gives us an exclusive insight into his brand-new, major BBC programme *The Planets*.

And, with Apollo 11's 50th anniversary just around the corner, what better way to prepare than to dust up on your knowledge of NASA? Enjoy your free eBook!

Gemma Lavender
Editor-in-Chief

Our contributors include…

Giles Sparrow
Space science writer
Step back to a time before NASA. Giles delves into spaceflight history to fill us in on the world's first steps in attempting to leave the confines of Earth.

Leo Bear-McGuinness
Space science writer
Galaxy X, a small, mysterious galaxy, could exist – that's according to brand-new evidence. Turn to page 16 for Leo's special report.

James Romero
Science writer
It's a particle, but it doesn't act like one. James reveals everything you need to know about the newly unveiled odderon – and what it tells us about space.

Lee Cavendish
Staff Writer
Lee caught up with Professor Brian Cox this month – but not before writing a handy guide to this year's total solar eclipse. Turn to page 32 for your observing tips.

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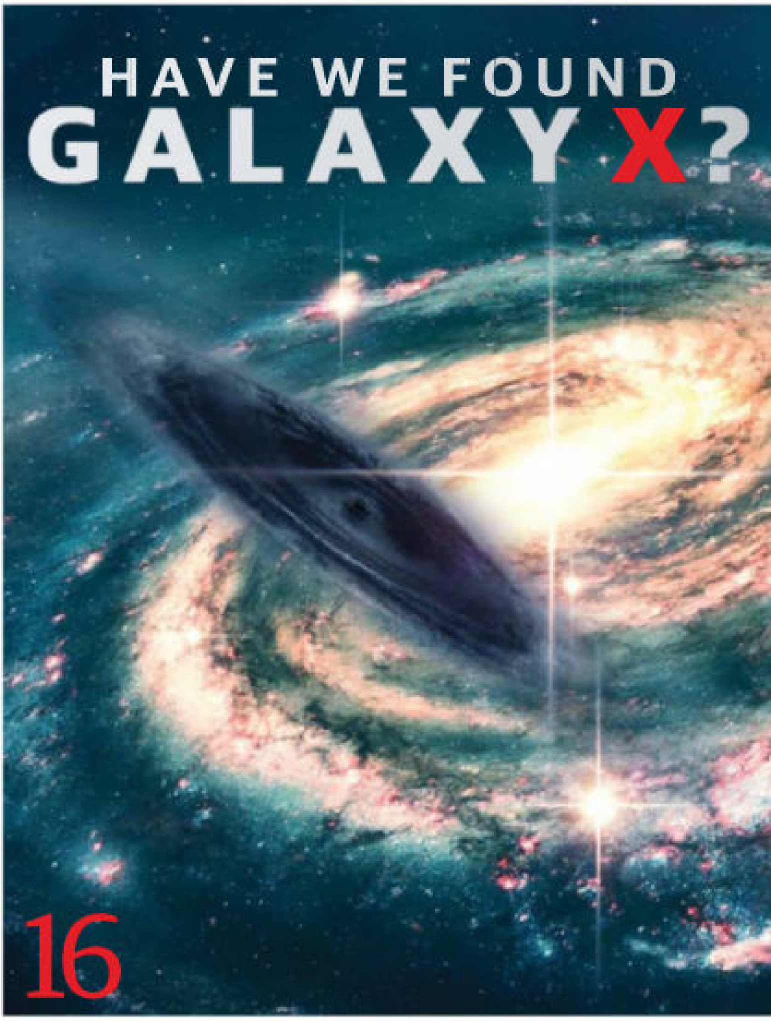

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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

ALMA's red-sky silhouette

These satellite silhouettes that sit in front of the red sky are just some of the satellites that make up the Atacama Large Millimetre/submillimetre Array (ALMA), which resides in the desert of Chile. There are 66 telescopes in total, and together they make up a world-class radio telescope array that has captured some amazing sights of the cosmos and provided vital data for research. The atmospheric conditions in the Atacama Desert are ideal for astronomy, as it is dry and mostly cloudless – providing roughly 300 clear nights a year – but can also provide some amazing scenic sights, such as this one.

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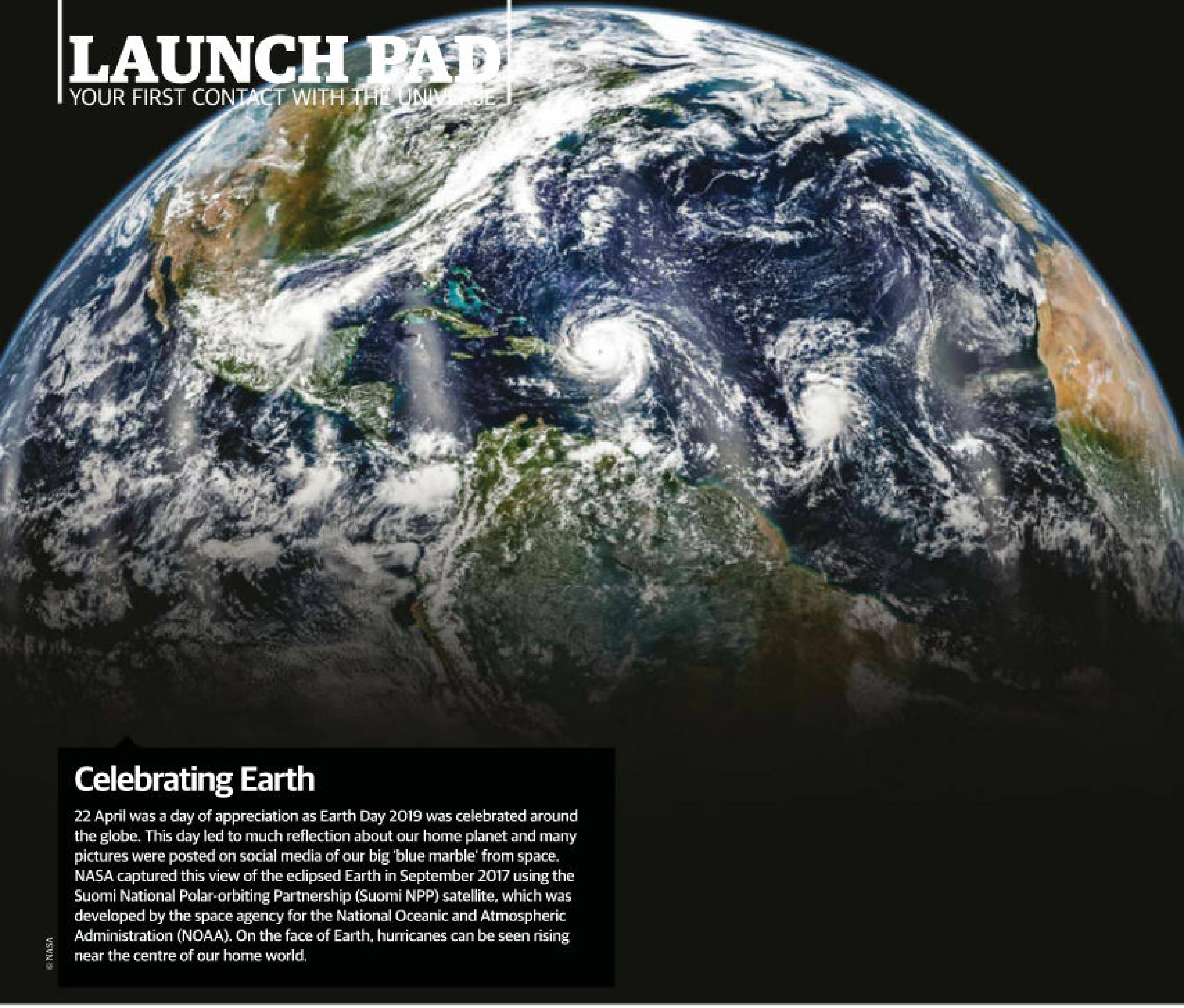

Celebrating Earth

22 April was a day of appreciation as Earth Day 2019 was celebrated around the globe. This day led to much reflection about our home planet and many pictures were posted on social media of our big 'blue marble' from space. NASA captured this view of the eclipsed Earth in September 2017 using the Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, which was developed by the space agency for the National Oceanic and Atmospheric Administration (NOAA). On the face of Earth, hurricanes can be seen rising near the centre of our home world.

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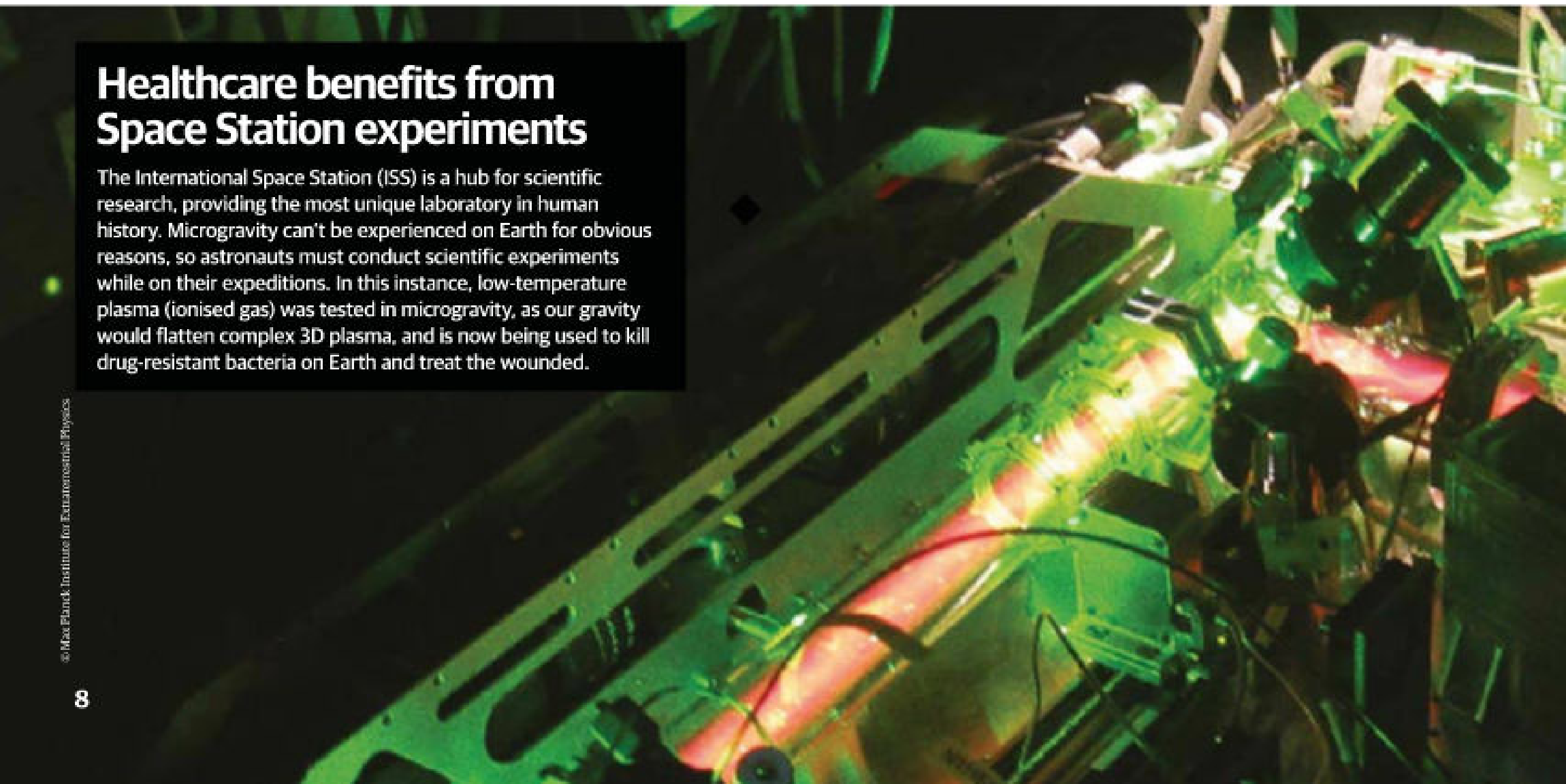

Healthcare benefits from Space Station experiments

The International Space Station (ISS) is a hub for scientific research, providing the most unique laboratory in human history. Microgravity can't be experienced on Earth for obvious reasons, so astronauts must conduct scientific experiments while on their expeditions. In this instance, low-temperature plasma (ionised gas) was tested in microgravity, as our gravity would flatten complex 3D plasma, and is now being used to kill drug-resistant bacteria on Earth and treat the wounded.

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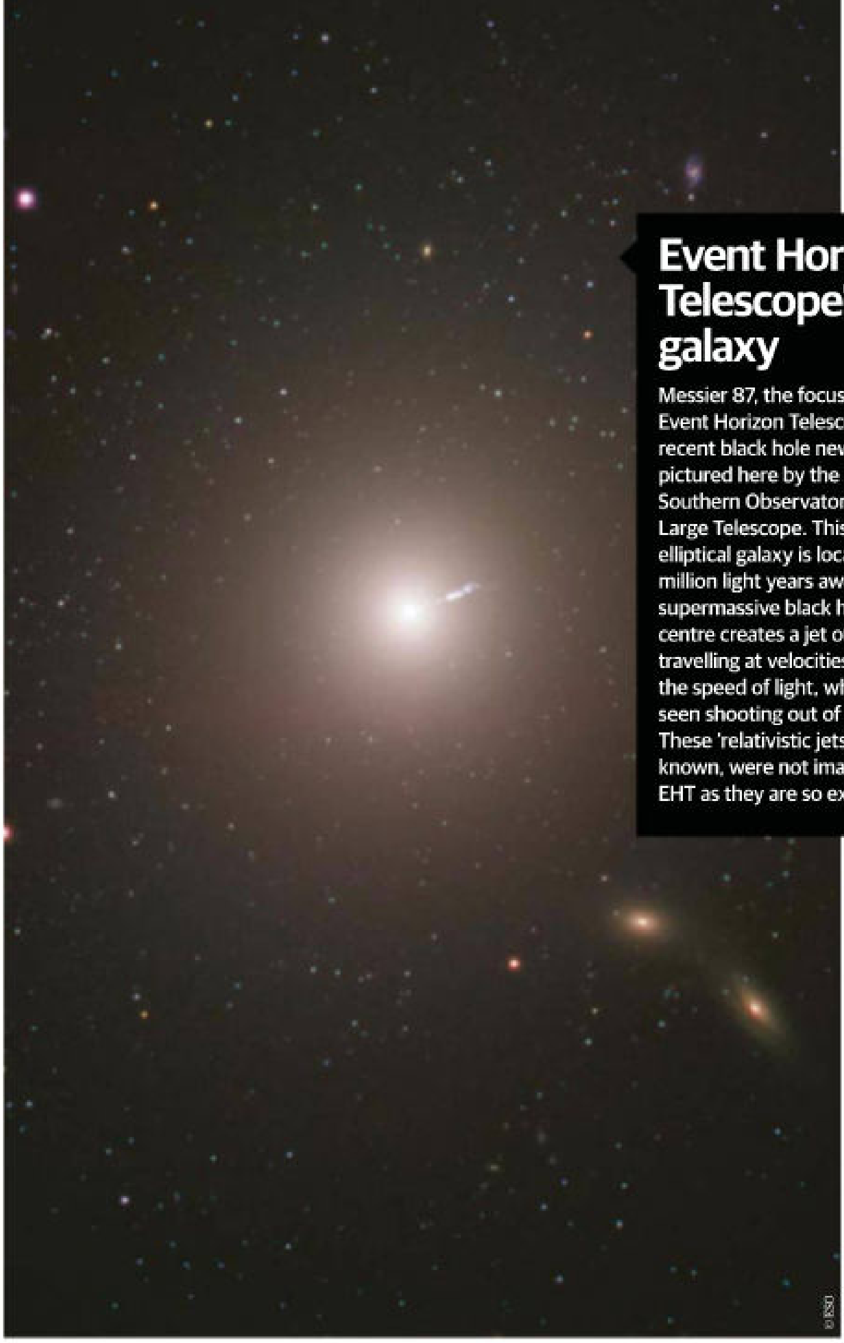

Event Horizon Telescope's galaxy

Messier 87, the focus of the Event Horizon Telescope (EHT)'s recent black hole news, has been pictured here by the European Southern Observatory's Very Large Telescope. This gigantic elliptical galaxy is located 55 million light years away, the supermassive black hole at its centre creates a jet of particles travelling at velocities close to the speed of light, which can be seen shooting out of its heart. These 'relativistic jets', as they are known, were not imaged by the EHT as they are so extensive.

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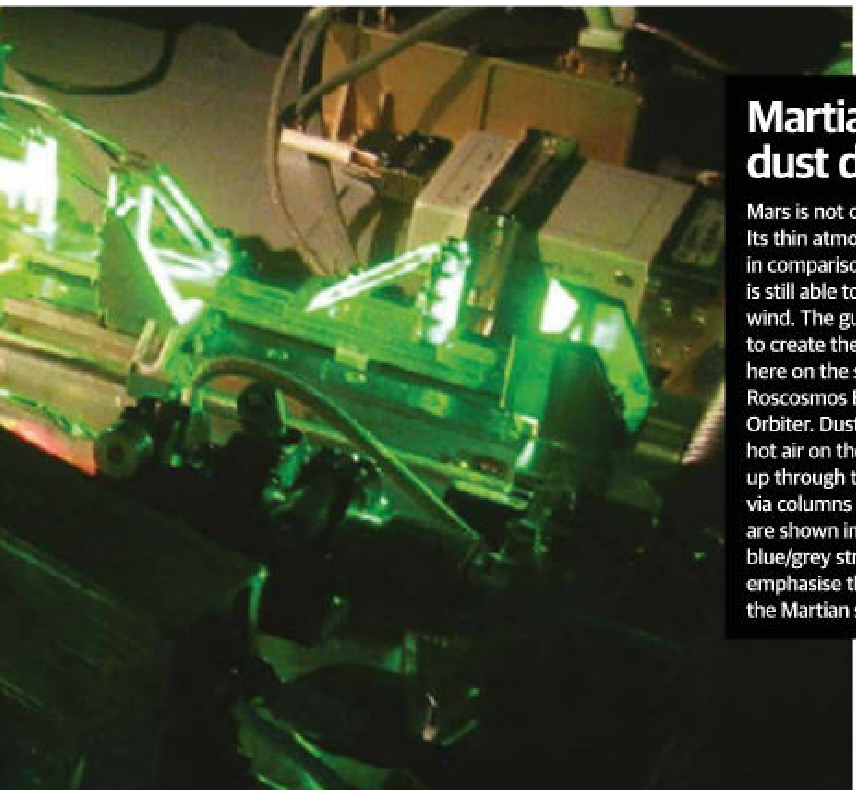

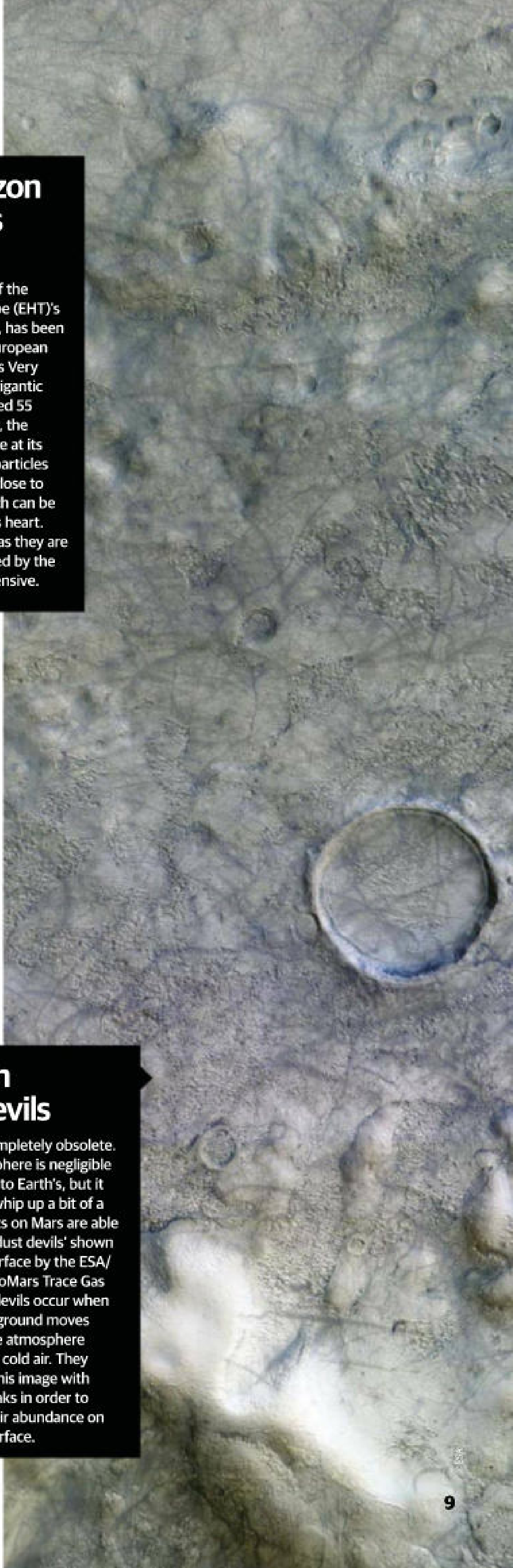

Martian dust devils

Mars is not completely obsolete. Its thin atmosphere is negligible in comparison to Earth's, but it is still able to whip up a bit of a wind. The gusts on Mars are able to create the 'dust devils' shown here on the surface by the ESA/Roscosmos ExoMars Trace Gas Orbiter. Dust devils occur when hot air on the ground moves up through the atmosphere via columns of cold air. They are shown in this image with blue/grey streaks in order to emphasise their abundance on the Martian surface.

© ESA

Somewhere over the rainbow

Northrop Grumman – a United States-based aerospace and defence technology company – recently launched a Cygnus spacecraft from NASA's Wallops Flight Facility in Virginia, United States. Its destination, the ISS. Within the Cygnus cargo spacecraft is 3,450 kilograms (7,600 pounds) of technology pivotal for scientific investigation including gels, tools to measure body fluids, wearable sensors to study ageing effects and even a fleet of small robots. This launch marked the 11th cargo flight to the ISS by Northrop Grumman, and it was treated to a rainbow in doing so.

© NASA

Preparing for Mars 2020

NASA's new Martian rover, Mars 2020, is due to launch around July 2020, pictured here undergoing some extensive examination at the Spacecraft Assembly Facility's High Bay 1 clean room at NASA's Jet Propulsion Laboratory in Pasadena, California, United States. Before the spacecraft can be launched engineers have to test the cruise stage extensively, as it holds the hardware that will guide the Mars 2020 rover to its intended destination.

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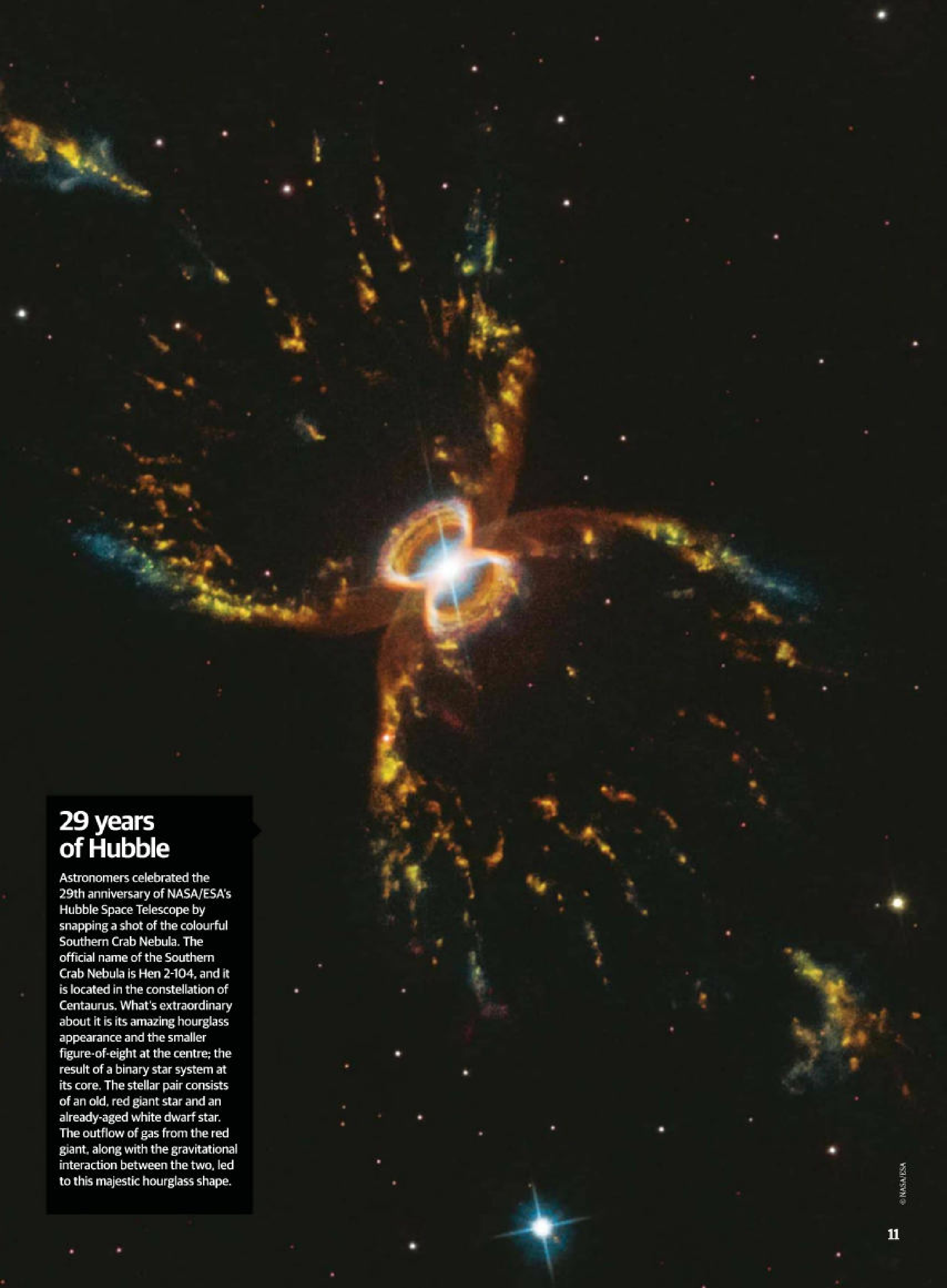


29 years of Hubble

Astronomers celebrated the 29th anniversary of NASA/ESA's Hubble Space Telescope by snapping a shot of the colourful Southern Crab Nebula. The official name of the Southern Crab Nebula is Hen 2-104, and it is located in the constellation of Centaurus. What's extraordinary about it is its amazing hourglass appearance and the smaller figure-of-eight at the centre; the result of a binary star system at its core. The stellar pair consists of an old, red giant star and an already-aged white dwarf star. The outflow of gas from the red giant, along with the gravitational interaction between the two, led to this majestic hourglass shape.

© NASA/ESA

We might need new physics to explain the universe

Words by **Mike Wall**

The universe is expanding faster than expected, suggesting that astronomers may have to incorporate some new physics into their theories of how the cosmos works, a new study reports.

The revised expansion rate is about ten per cent faster than that predicted by observations of the universe's trajectory shortly after the Big Bang, according to the new research. The study also significantly reduces the probability that this disparity is a coincidence, from 1 in 3,000 to just 1 in 100,000.

"This mismatch has been growing and has now reached a point that is really impossible to dismiss as a fluke," study lead Adam Riess, a professor of physics and astronomy at The Johns Hopkins University in Baltimore, US, said in a statement.

"This is not what we expected," said Riess, who won the Nobel Prize for physics in 2011, along with Brian Schmidt and Saul Perlmutter, for showing, in the late 1990s, that the universe's expansion is accelerating. It's unclear what's driving this surprising acceleration, but many astronomers invoke a mysterious, repulsive force called dark energy.

In the new study, Riess and his colleagues used the Hubble Space Telescope to study 70 Cepheid variable stars in the Large Magellanic Cloud (LMC), one of the Milky Way's satellite galaxies. Cepheid variables dim and brighten at predictable rates and are therefore 'standard candles' that allow astronomers to calculate distances.

Riess and his team also incorporated observations made by the Araucaria Project, a collaboration involving researchers in the United States, Europe and Chile who studied various LMC binary star systems, noting the dimming that occurred when one star passed in front of its neighbour. This work provided additional distance measurements, helping the study team to improve their understanding of the Cepheids' intrinsic brightness.

The researchers used all of this information to calculate the universe's present-day expansion rate, a value known as the Hubble constant after American astronomer Edwin Hubble. The new number is about 74.03 kilometres (46 miles) per second per megaparsec – one megaparsec is roughly 3.26 million light years.

The 'expected' expansion rate, by contrast, is about 67.4 kilometres (41.9 miles) per second per megaparsec. This projected rate is based on observations that Europe's Planck satellite made of the cosmic microwave background – the light left over from the Big Bang that created the universe 13.82 billion years ago.

"One is a measurement of how fast the universe is expanding today, as we see it. The other is a prediction based on the physics of the early universe and on measurements of how fast it ought to be expanding," Riess added. "If these values don't agree, there becomes a very strong likelihood that we're missing something in the cosmological model that connects the two eras."

> "This mismatch has been growing and has now reached a point that is really impossible to dismiss as a fluke" **Adam Riess**

The universe is expanding at a rate that's ten per cent faster than predicted

© SKA Organisation/Swinburne Astronomy Productions

Secrets of tiniest star ever revealed by passing asteroids

Words by **Samantha Mathewson**

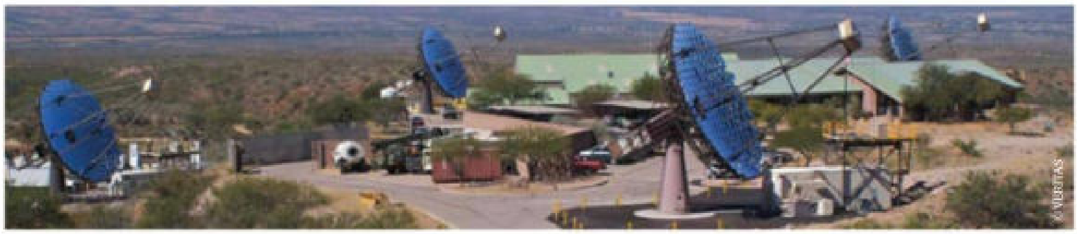
Most stars in the night sky are too far away to be measured accurately, even by the best optical telescopes. However, astronomers leveraged a method known as diffraction to overcome the challenge.

Diffraction occurs when an object, such as an asteroid, passes in front of a star, creating a shadow called an occultation. As the asteroid passes in front, astronomers can calculate how long it takes for the light to fade. Knowing how fast the asteroid is travelling, astronomers can then determine the size of the star, and more precisely measure the diameter of several distant stars.

Using the Very Energetic Radiation Imaging Telescope Array System (VERITAS) at the Fred Lawrence Whipple Observatory in Amado, Arizona, astronomers carefully tracked the asteroid Imprinetta as it passed in front of the star TYC 5517-227-1 on 22 February 2018. Roughly 300 images per second were captured to accurately measure the diffraction pattern in the asteroid's shadow.

Data from VERITAS revealed that the diameter of the star, which is 2,674 light years from Earth, is 11-times greater than that of Earth's Sun. This star, now classified as a red giant, is thus much bigger than previously thought.

Astronomers were able to repeat this new technique when the 88-kilometer (55-mile) wide asteroid named Penelope passed in front of the Sun-like star TYC 278-748-1 on May 22 2018. This star, located 700 light years from Earth, is the smallest star measured in the night sky to date, the researchers said.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Marsquake! NASA's InSight lander feels its first Red Planet tremor

Words by **Meghan Bartels**

Scientists just felt the Red Planet move under their feet – robotically from millions of miles away – on the surface of Mars.

On 6 April, NASA's InSight lander sensed its first confirmed marsquake, a phenomenon scientists suspected, but couldn't confirm, on our neighbouring planet. Measuring the Martian equivalent of earthquakes was among the lander's key science goals.

"We've been waiting months for our first marsquake," Philippe Lognonné, the principal investigator for the seismometer instrument, said in a statement released by the French space agency, which runs the instrument with the national research centre. "It's so exciting to finally have proof that Mars is still seismically active."

Scientists never thought marsquakes would be as frequent as their terrestrial equivalents because Mars doesn't sport the tectonic plates whose jostling interactions prompt quakes on Earth. But they suspected that the stress caused by the slow cooling of the body could trigger sporadic quakes as energy rippled through the planet's interior.

The tentatively confirmed signal may have company from similar tremors measured on 14 March, 10 April and 11 April, but scientists aren't positive yet what triggered those and can't confirm as of yet if their shakes reflect interior activity.

InSight has confirmed its first marsquake

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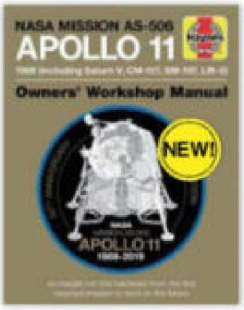

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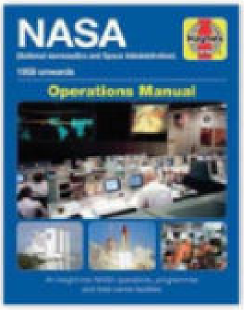

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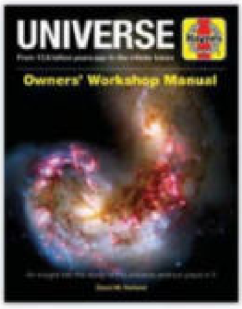

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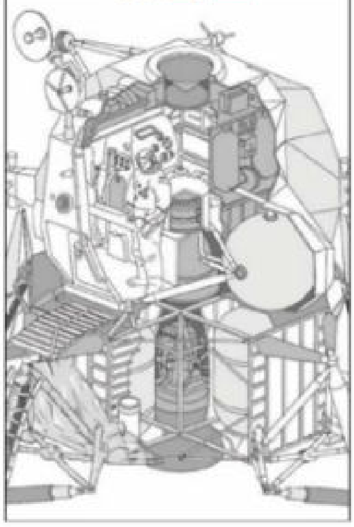


Astronomers finally spot universe's first molecule

Words by **Samantha Mathewson**

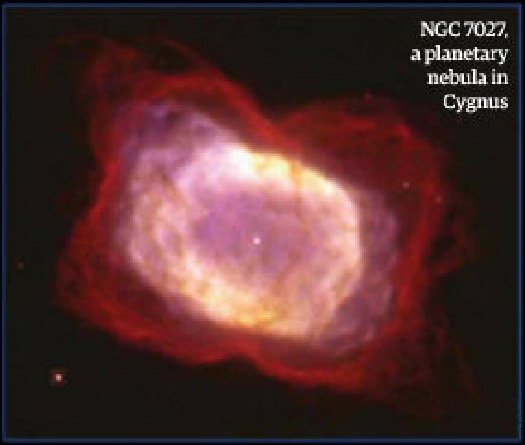
A flying observatory has pinpointed the first type of molecule that formed in the universe after the Big Bang. Helium hydride – a combination of helium and hydrogen – was detected roughly 3,000 light years from Earth by NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA). The molecule was found in a planetary nebula, NGC 7027, the dusty remnant of a Sun-like star.

For hundreds of thousands of years after the Big Bang, the universe was too hot and too full of radiation for atoms to bond together. At that time, only a few types of atoms existed, including hydrogen, helium and lithium. However, the new study shows that 100,000 years after the Big Bang, the universe cooled enough for helium and hydrogen to combine, forming the molecule known as helium hydride.

While helium hydride has been produced and tested in a laboratory setting, this discovery marks the first time that the molecule has been detected in space – which sheds light on the chemistry of the early universe, according to a statement from NASA.

"This molecule was lurking out there, but we needed the right instruments making observations in the right position – and SOFIA was able to do that perfectly," Harold Yorke, director of the SOFIA Science Center in California's Silicon Valley, said in the statement.

Once the universe cooled down, hydrogen atoms started to interact with helium hydride, creating molecular hydrogen, which set the stage for star formation. From that point on, stars created the other elements of the cosmos, according to the statement.


NGC 7027, a planetary nebula in Cygnus

© NASA

NGC 7027 has been a location of interest for helium hydride since the late 1970s. Ultraviolet radiation and heat from the aging star led scientists to believe that its environment would be suitable for helium hydride to form. However, astronomers were unable to confirm this theory until now.

> "This molecule was lurking out there, but we needed the right instruments making observations in the right position" **Harold Yorke**

Tiny Mercury may have a solid metallic core that rivals Earth's

Words by **Meghan Bartels**

A solid metallic core nearly as large as Earth's might be lurking deep within the Solar System's smallest planet, according to new research based on data gathered by NASA's Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) mission. That spacecraft spent four years circling the tiny planet before intentionally crashing on Mercury's surface. Now, scientists have used data from near the end of the probe's mission to peer deeper than ever into the planet.

© NASA/JPL

As the MESSENGER spacecraft orbited the tiny planet, the probe pinpointed the poles that Mercury rotates around. One of the instruments aboard also carefully measured small variations in local gravity.

Those variations cause a spacecraft to speed up or slow down, just a hair, and are the result of patches of the planet that are more or less dense than the average. They were particularly detailed near the end of the spacecraft's mission, when engineers sent the probe as close as 105 kilometres (65 miles) above the planet's surface.

Combining that information, scientists could build a detailed model of the tiny planet, then play around with variables like the size of a solid inner core and compare the results with reality. That modelling suggested both that Mercury should have a solid inner core and that this core should be quite large.

In fact, their most compelling model setting featured a solid inner core 2,000 kilometres (1,260 miles) across. That's about half the size of Mercury's entire core, which takes up 85 per cent of the planet. Even by terrestrial standards it's huge; Earth's solid inner core is about 2,400-kilometres (1,500-miles) wide.

Third planet found in two-star 'Tatooine' system

Words by **Mike Wall**

A third world lurks in the two-star Kepler-47 system, and it's bigger than its two siblings, a new study reports. "We certainly didn't expect it to be the largest planet in the system," study co-author William Welsh, an astronomer at San Diego State University, said in a statement. "This was almost shocking."

Kepler-47 is a roughly 3.5 billion year old system located 3,340 light years from Earth. One of its stars is quite Sun-like, but the other is considerably smaller, harbouring just one-third the mass of our Sun. The two stars orbit their common centre of mass once every 7.45 Earth days.

Kepler-47b and c complete one lap around the circumbinary system every 49 and 303 Earth days respectively. Kepler-47d's orbital period is 187 Earth days, which means it's the middle planet. And that came as a surprise; the team thought any additional planets in the system would probably be exterior to Kepler-47c.

These three alien worlds are unlike anything in our own backyard, said Jerome Orosz, also of San Diego State. They're much less dense than Saturn, which is the puffiest planet in our Solar System.

Such extreme puffiness is common for scorching 'hot Jupiter' alien worlds, which circle their host stars very tightly. But it's unusual for relatively temperate planets such as the Kepler-47 trio.

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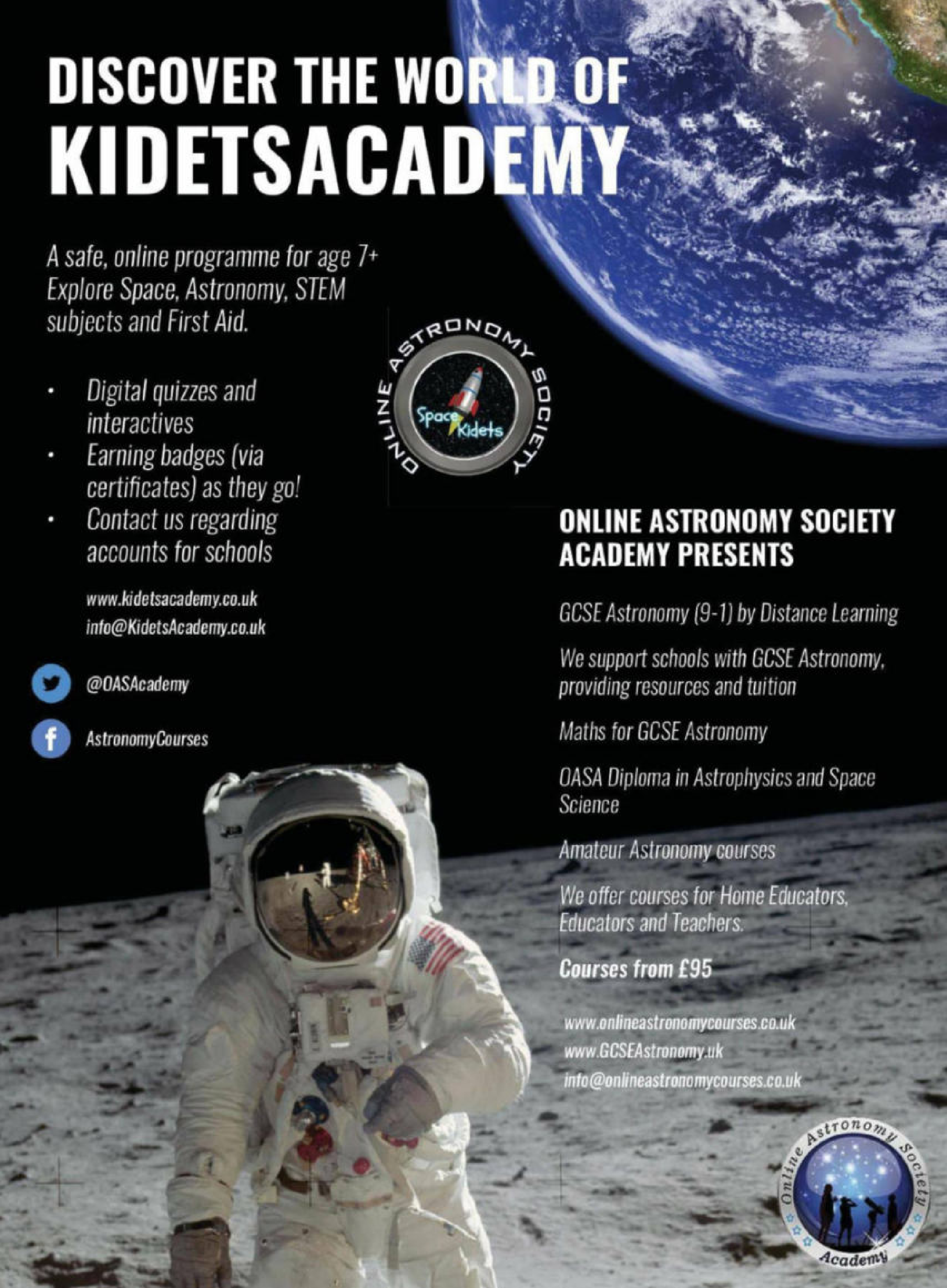
Three worlds have now been discovered around a binary



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HAVE WE FOUND GALAXY X?

Are astronomers any closer to pinpointing the mysterious object packed with dark matter?

Reported by Leo Bear-McGuinness & Ian Evenden

We like to think of our galaxy as a lone wanderer through the cosmos, solitarily spinning in the intergalactic gloom. But we are not alone in the universe - we have company along for the ride. Dwarf galaxies surround our own galactic swirl. Staying within 1.4 million light years of our galaxy's rim, dozens of these petite galaxies have already been discovered. But astronomers believe there is at least one more out there, a cluster of unknown matter hidden at the edge of the Milky Way: Galaxy X.

Theorised for years, Galaxy X is thought to be around one per cent the mass of the Milky Way, 300,000 light years from its centre and consisting almost entirely of dark matter, the mysterious substance said to make up 23 per cent of the universe's mass. But it's still just a theory. While astronomers have the mathematic calculations to believe the secretive galaxy exists, they've yet to find any concrete evidence. Despite their best efforts, it has stubbornly remained theoretical. But all that might soon change in the weeks to come...

"I started looking for Galaxy X about ten years ago, so I feel quite old talking about this," quips Sukanya Chakrabarti, an assistant professor of physics at the Rochester Institute of Technology. After authoring a paper on the potential existence of the galaxy in 2009, Chakrabarti has since become the world's lead investigator in the hunt for Galaxy X. And as she admits, it's been a long quest.

Back in 2009, she and fellow astronomer Leo Blitz analysed variations in the distribution of gas found at the edge of the Milky Way, and they couldn't easily explain what they found. "It showed very large perturbations on the outskirts of the edges of our galaxy," says Chakrabarti. "This is well beyond the solar circle, so you wouldn't expect such large perturbations." Now, at this stage in any other hunt for a celestial object, Chakrabarti might have turned to telescopic data and looked for the disturbance herself. But with Galaxy X, nothing is ever simple.

"I didn't make life easy for myself," she jokes. "The calculations preferred a co-planar merger - that is, the dwarf galaxy was orbiting roughly in the same plane as the Milky Way. And that means that if you were trying to look for it, you'd be having to deal with the dust obscuration close to the plane of the galaxy." Unlike many dwarf galaxies, Galaxy X didn't seem to be hovering above or below the Milky Way's plane, which would make it easier to see. Instead, the elusive system appeared to be

Above: The distribution of dark matter in the centre of the giant galaxy cluster Abell 1689, containing about 1,000 galaxies and trillions of stars, as captured by the Hubble Space Telescope

Right: Urbain Le Verrier, the French astronomer who predicted the location of Neptune

© NASA; ESA; ESO; Gemini Observatory/AURA; Giuseppe Donatiello

hidden right at the edge of the Milky Way's disc, and so would be completely obscured by the giant expanse of dust and gas between it and Earth.

"So, if you look above the plane, you'll see other dwarf galaxies which are easily visible because they're well off the plane of the galaxy," says Chakrabarti. "But if you're looking through dust, it's like looking through a smoke screen. So that's why a lot of these surveys for dwarf galaxies have largely avoided the galactic plane. And that's also why most of the discoveries of dwarf galaxies so far have been well above it."

Undeterred, Chakrabarti opted for a different search tactic. Instead of looking for Galaxy X directly, she studied everything else in its supposed region and scraped information about the dwarf galaxy's behaviour through what couldn't be seen. These experiments began with computer simulations of the Milky Way and its known dwarf galaxies, and perturbations at the simulated galaxy's edge soon showed up. "I included the gravitational effects of the three most massive dwarf galaxies of the Milky Way - these are the Large Magellanic and Small Magellanic Clouds and the Sagittarius Dwarf Galaxy," she explains. Floating less than 200,000 light years from Earth, these satellite galaxies and their millions of stars can be seen from the Southern Hemisphere and even helped early Polynesian cultures navigate the seas. "I gave them those orbits to see how close a perturbing dwarf galaxy would have to get to produce the observed disturbances in the outer gas disc of the Milky Way. They were the most realistic simulations that I could do," she adds.

"And I found that even after including the gravitational effects of all the known players of the Milky Way, you still couldn't explain the observed disturbances in the outer gas disc. So I concluded that we needed a new dwarf galaxy that had not yet been identified in 2009. And that's really when I put on my observer's hat and started to look for it myself."

Her observer's hat donned and curiosity piqued, Chakrabarti spent the next few years hunting

Left: Neptune's north pole, as seen by NASA's Voyager 2

Below: A Cepheid variable star, a type of star detected within Galaxy X, taken in the Milky Way by the Hubble Space Telescope

> "Even after including the gravitational effects of all the known players of the Milky Way, you still couldn't explain the disturbances" **Sukanya Chakrabarti**

Dark matter galaxies

Though hypothetical, these galaxies could be real examples

Dragonfly 44

This strange galaxy has around the same mass as the Milky Way, yet hardly any stars shine from its disc - only one per cent the number seen in our home galaxy. This means it emits only one per cent of the light too, making it difficult to identify.

Dark matter	Visible matter
0.1%	99.9%

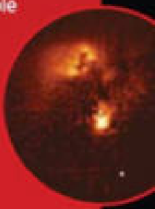
Segue 3

Smaller galaxies tend to be proportionately richer in dark matter. The galaxy with the lowest known mass, Segue 3 in the constellation of Pegasus, has 600-times more dark matter than normal matter. A more usual ratio is 5:1.

Dark matter	Visible matter
98.83%	0.17%

HE0450-2958

A quasar apparently floating freely in space. It may be a supermassive black hole ejected from a nearby star-forming galaxy, a misidentification of a luminous galaxy as a quasar or a host galaxy so dim the quasar completely outshines it.

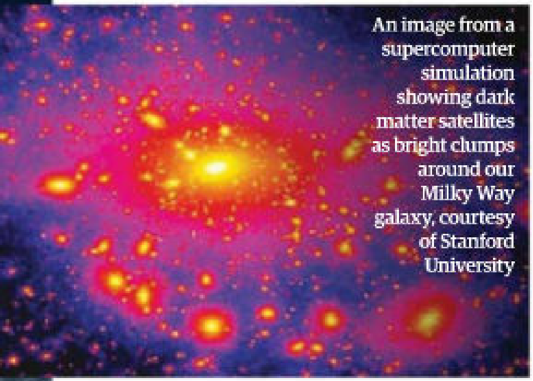


Dark matter	Visible matter
??%	??%

NGC 1052-DF2

This ultra-diffuse galaxy in Cetus is one of two that appear to have little or no dark matter. Despite this the galaxies hold together, possibly suggesting that what we call 'dark matter' may be an unknown effect of normal matter's gravity.

Dark matter	Visible matter
0.25%	99.75%



An image from a supercomputer simulation showing dark matter satellites as bright clumps around our Milky Way galaxy, courtesy of Stanford University

> "To be convinced that a distant galaxy is real, a sample of stars at a particular distance on the sky must be convincing" **Alice Quillen**

through spectroscopic surveys of space, searching for any clue that could lead her to the missing phenomena. And, in 2015, she and her colleagues found just that: four bright, variable stars right where Galaxy X should be. It was just the kind of sign they needed.

"To find a dwarf galaxy, you try to find stars that are in it," explains Alice Quillen, a professor of physics and astronomy at the University of Rochester. Lending her significant expertise to the Galaxy X quest, Quillen helped write the 2015 paper that further pinpointed the dwarf galaxy on the map. "Dwarf galaxies are very diffuse," she adds. "So to be convinced that a distant galaxy is real, a sample of stars at a particular distance on the sky must be convincing." And fortunately for Quillen and her colleagues, the stars found in 2015 were very convincing, at least for them.

"We found that they were all coherently receding," says Chakrabarti. "That is, they were all moving away from us with roughly the same velocity, which was comparable to what you expected from the dynamical models. So we believed that these stars could either be part of Galaxy X or part of a tidal stream that was produced by it."

Perturbations in outer space, a hypothesised cause and calculations to prove its existence; in many ways, Chakrabarti's quest for Galaxy X is a mirror story to Urbain Le Verrier's discovery of Neptune in the 1800s. Like Chakrabarti, the French astronomer first observed discrepancies with celestial orbits. Uranus' elliptical path didn't seem to make sense if there wasn't another hidden planet affecting its trajectory. Sure

The Milky Way

The galaxy we call home is hard to map, since we can't observe it from outside

You are here
Our Solar System lies in the Orion Arm of the Milky Way's spiral, approximately 26,000 light years from the galactic centre.

Bullet cluster
This recent galactic merger's gravitational mass is not where it should be based on observations, so something invisible must be having an effect on its gravity.

Galaxy X?
On the other side of the galactic centre, hidden by the disc, the proposed location of Galaxy X is 290,000 light years from us.

Seeing the unseeable

Although yet unobserved, there are some telltale signs of Galaxy X

Perturbed edge of Milky Way

Something was disturbing the hydrogen gas at the edge of our galaxy. These can reveal the distance, location and mass of a satellite galaxy that can't be seen in visible light. The gas can be mapped with radio telescopes, and mathematical analysis of this data reveals the galaxies.

Stars that brighten and dim

Four Cepheid variable stars were found 300,000 light years away using the VISTA infrared telescope, which can see through some of the dust at our galaxy's core. The Milky Way only extends 48,000 light years in their direction, so they must be in another galaxy.

Smith's Cloud

A massive cloud of gas that withstood a pass through the Milky Way 70 million years ago and is now coming back for more. To have survived, it is hypothesised, it may be embedded in its own dark-matter halo. It will hit the Perseus Arm in roughly 30 million years.

Milky Way dark-matter halo

As much as 95 per cent of our galaxy is made up of dark matter, extending well beyond the visible galaxy into intergalactic space. It is densest in the centre, roughly spherical and gets less dense as distance from the centre increases.

Large Magellanic Cloud

As our largest satellite galaxy approaches, its dark-matter halo interacts with the Milky Way's, a phenomenon known as its 'dark matter wake'. Scientists can see this in changes to the movements of stars in the LMC's direction.

Andromeda Galaxy

Although it appears larger than the Milky Way, Andromeda weighs about the same because it has less dark matter. This will become very important when the two galaxies merge in 4.5 billion years' time.

Other satellite galaxies

Galaxies such as the Sagittarius Dwarf and Small Magellanic Cloud each have their own dark-matter haloes. Their mass increases as the galaxies merge.

© Tobias Roetsch; Kasantzidis

Catching a GLIMPSE of Galaxy X

The Galactic Legacy Infrared Mid-Plane Survey Extraordinaire, or GLIMPSE, uses the Spitzer space telescope to survey the galactic plane, meaning that it will cover the area Galaxy X is expected to be in.

Spitzer is an infrared telescope, meaning it can pick up on radiation passing through the galactic core, an area that blocks visible light and generates a lot of radio waves that can interfere with observations.

Spitzer was launched by NASA in 2003 from Cape Canaveral with a planned mission lasting 2.5 years, but is still operational today. Subsequent launches of observational telescopes, such as the Wide-field Infrared Survey Explorer (WISE) in 2009 and the James Webb Space Telescope in 2021, have – and will – increase our ability to hunt out Galaxy X and others like it.

> "The kind of dwarf galaxies that we've been finding lately are much fainter than we had ever hoped we'd be able to find" **Sukanya Chakrabarti**

Right: The Small Magellanic Cloud, a dwarf galaxy captured in infrared light from the Herschel Space Observatory, a European Space Agency-led mission, and NASA's Spitzer Space Telescope

Below: The Large Magellanic Cloud, a satellite galaxy to the Milky Way, as seen from NASA's Spitzer Space Telescope

enough, Le Verrier's prediction was right, and Neptune was found within one degree of his calculations. It was the first time in history that any hidden object had been discovered just through analysis of its gravitational imprints on another celestial body.

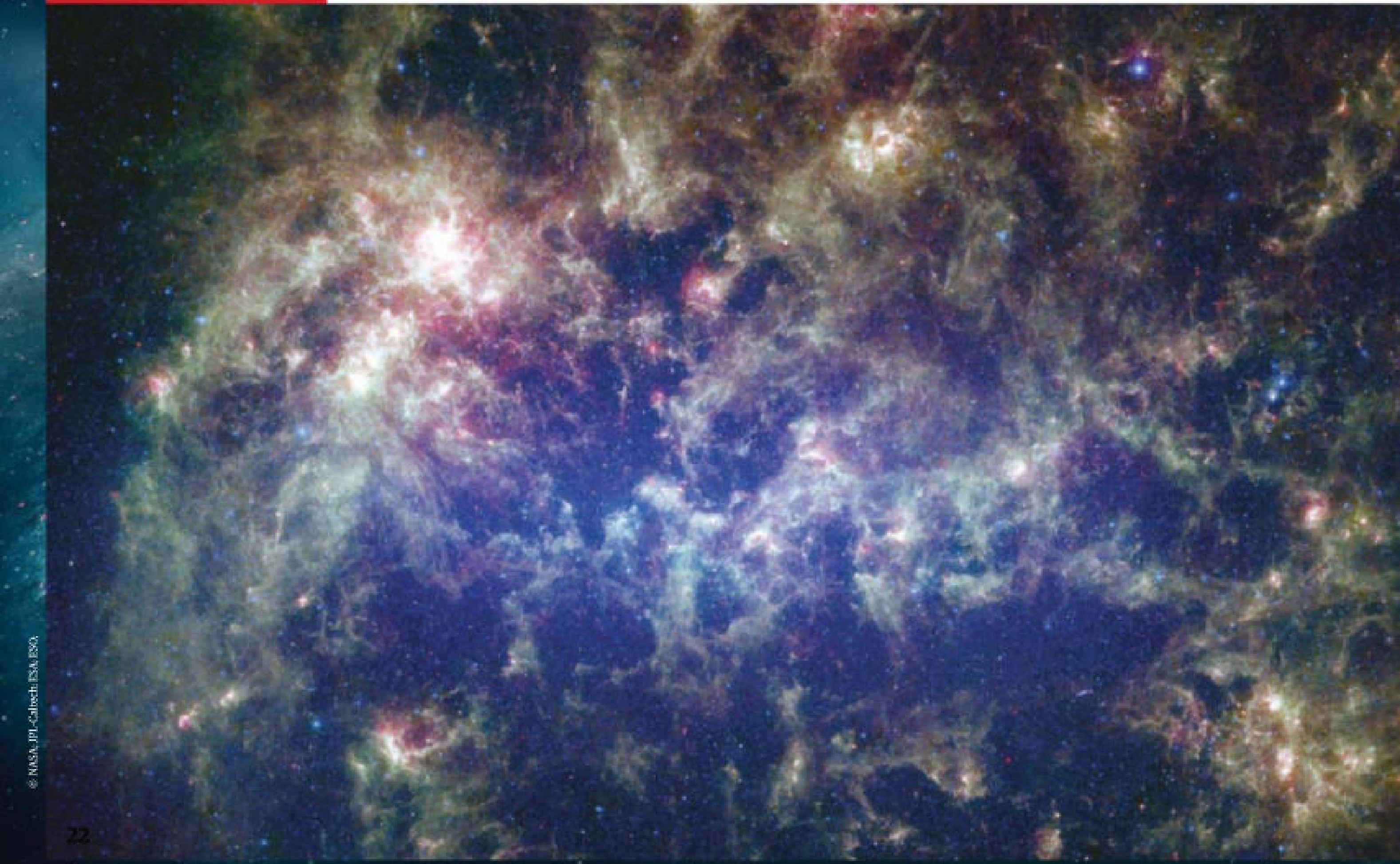
But Galaxy X is different; proof of its existence has yet to be published. And without this hard evidence, the scientific community has been a little less accepting than it was for Le Verrier. Some astronomers have even rebuked the existence of the galaxy altogether. Writing in the *Astrophysical Journal Letters* in 2015, one group of scientists discredited the stars found by Chakrabarti and Quillen as "spotted objects" and claimed that there was no evidence for a dwarf galaxy at all. Suffice to say, Chakrabarti was less than pleased about the community's scepticism.

"I can't say that I was thrilled about it," she jokes. "Scientists are sceptical in general and discoveries are hard to prove, so this was probably no different in that sense." Healthy scepticism or not, the challenge quickly deepened Chakrabarti's resolve. Now she and her colleagues had both a galaxy to prove real, and a paper to prove wrong. More evidence was desperately needed and, in 2017, they found it.

"We did refine several things in our 2017 paper," Chakrabarti explains. "In addition to getting light curves to identify the variable star candidates, we also got spectra [more data from the near-infrared spectrum]. And by looking at the spectra we got a completely independent piece of information, independent to the light curves. And that is really why we did it, because we wanted it to be found in a very unbiased way."

With this added information Galaxy X was brought back to the realms of possibility, and the quest reinvigorated. The 2015 challenger paper had rocked the hunt's foundations, but they were now rebuilt stronger than ever. "That's just the nature of science," Chakrabarti admits. "You are continually trying to refine what you did." And so the search marches on, ten years after it first began. But is there any hope that Galaxy X's smoking gun could be found before the pursuit reaches its next decade? Without giving much away, Chakrabarti hints that such a revelation could be just around the corner.

"There might be, on the horizon, some more news about Galaxy X soon," she confides. "We're



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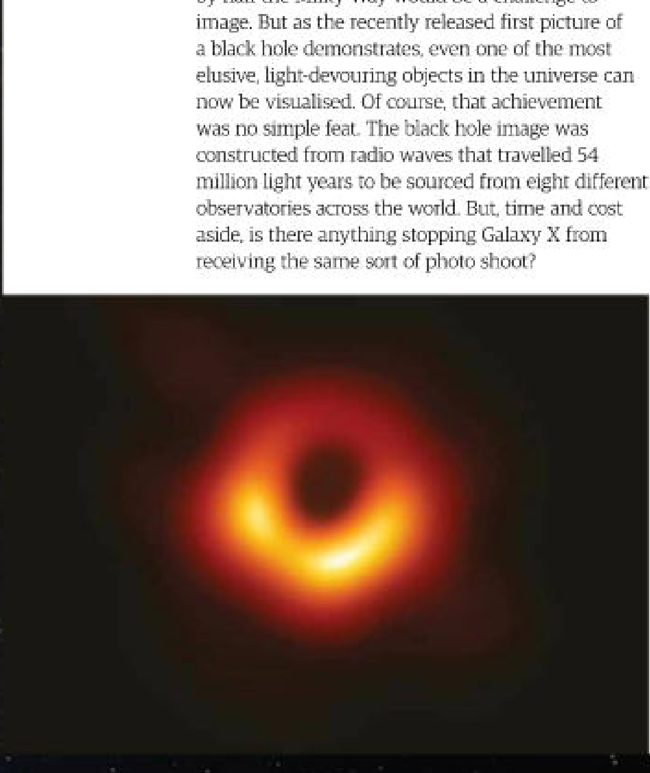
Below: **The first-ever image of a black hole, as taken by the Event Horizon Telescope**



at this stage right now where we've gone through a particular candidate and we're in the process of writing the paper, which is about 50 per cent done." But while a new candidate could lend the quest some more credibility, a photograph would be the trophy that could finish the hunt altogether. Unfortunately, any dark-matter object obscured by half the Milky Way would be a challenge to image. But as the recently released first picture of a black hole demonstrates, even one of the most elusive, light-devouring objects in the universe can now be visualised. Of course, that achievement was no simple feat. The black hole image was constructed from radio waves that travelled 54 million light years to be sourced from eight different observatories across the world. But, time and cost aside, is there anything stopping Galaxy X from receiving the same sort of photo shoot?

After posing the question to Chakrabarti, the astronomer clearly becomes animated with classified knowledge, and stifles any announcements before they slip out. "I'm having difficulty answering the question, because that's one of the things I've been writing about right now. So what I want to say at the moment is that the chances are very good.

"Seeing it in radio would mean that it has to have gas, but seeing it in the optical is very possible now with the new surveys that are ongoing. And the kind of dwarf galaxies that we've been finding lately are much fainter than we had ever hoped we'd be able to find. I think the chances of getting an optical image are really, really good, so stay tuned on that. There will probably be some news on that very, very shortly - some big news."

While Chakrabarti remains tight-lipped, it's clear that the quest for Galaxy X is about to get a lot more interesting. And as the dwarf system is thought to consist almost entirely of dark matter, any information about its nature could have far-reaching revelations about the mysterious substance and its role in the universe. But for Chakrabarti and her colleagues, the most tantalising prospect of Galaxy X is the galaxy itself. Sought after for over a decade, any subsequent facts and figures from its discovery will undoubtedly pale in comparison to the actual find. X may mark the spot for future research and astronomical studies, but after years of searching, just the confirmation of another companion in our endless drift through the universe would be enough to make both journeys worthwhile.

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INTERVIEW BIO

Professor Brian Cox

Brian Cox OBE is a popular science communicator, professor of particle physics at the University of Manchester, England, and former rock star. His work has been viewed and read by millions, with multiple books explaining complex areas of science and astronomy as well as his popular BBC television series *Wonders of the Solar System* in 2010, co-presenting *Stargazing Live* and soon his brand new show *The Planets*.

His ability to explain science to a wide audience of people with different levels of scientific knowledge is what has made him so popular. He has also collected numerous accolades for his efforts.

BRIAN COX THE ORDER OF THE SOLAR SYSTEM

All About Space speaks to the physicist about our unique place in the universe ahead of his new show *The Planets* and reveals what he believes will be the future in the colonisation of the Red Planet

Interviewed by Lee Cavendish

It was back in 2010 when you released *Wonders of the Solar System*. That was a landmark series. What is new about *The Planets*?
I think what's been remarkable over the last decade is the amount of detail that we've been able to put into the story of the Solar System, mainly proven by new missions. If you go back to 2009, when we were making *Wonders of the Solar System*, Cassini had only just arrived at Saturn.

Then this grand tack model, as it's called, which seems fantastical and contrived, is only a recent development based both on observations from space probes and an increased sophistication in computer modelling of the Solar System. Thirdly, the increasing number of observations of other solar systems. It's critically important for our understanding of the Solar System today that we've now seen well over 3,000 planets around distant stars, and what we've seen is that the geography and the layout of other solar systems are not like ours in general.

So it's a combination of a lot of data from a lot of spacecraft. What's quite exciting from a scientific perspective is that [NASA's spacecraft] Juno, which is providing magnificent images - very strange images of Jupiter and its poles with its different colours and swirling clouds - that spacecraft has not really had an impact yet on our pitch of the development of Jupiter in the Solar System, as the data is just coming back.

The aim of that spacecraft is to really try and take a cross section through Jupiter so we can see what the planet is made up of. A 3D description of Jupiter straight through, which will allow us to understand more about how it formed. In a way it's a much bolder series intellectually in that sense because things like the grand tack model have only been around for a couple of years, and it's unusual to put those kinds of cutting-edge theories into landmark television. It tends to be much more conservative.

The difference is that there's an underlying philosophy to the series - it's why I like the Jupiter episode in particular for this reason - and the philosophy is that the Solar System is a system. I think that's what is surprising and an important point, because it's quite natural for us to focus our eyes on the Earth alone and think we're isolated from the goings on in the rest of the universe. This is not the case. There are very practical reasons as to why we need to pay attention.

Was there anything you learned from filming *The Planets* that you didn't know before?
Absolutely! So the grand tack model that I just spoke about is one of them. In the context of those models, we see that the evolution of the Solar System is extremely complicated. That's the first thing. Secondly, when we were dealing with the planet Mercury - and it comes partly from these computer models again - the idea that Mercury almost certainly formed much further away from the Sun. This is a very new idea. It's based on a spacecraft that went there and observed the chemical composition of the surface and returned these tremendous surprises, particularly about elements called sulphurous and phosphorus

> "It's quite natural for us to focus our eyes on the Earth alone and think we're isolated from the rest of the universe"

Below: The Solar System as we see it has had a very dynamic history

Right: The Europa Clipper mission will study the potentially habitable moon of Jupiter

on the surface, which were not present close to the Sun when the planets were forming. They only existed in large quantities further out in the Solar System.

Observations like that, when you begin to piece them together with the modelling, tell you that our Solar System is significantly more dynamic in terms of the geometry of the Solar System today - it was not the same geometry when it began.

I think we tend to think of our Solar System as a fossilised remnant of the initial dust cloud that collapsed. So the initial structure around the Sun 4.6 billion years ago or so is echoed in the distribution of planets today around the Sun. What we've learnt recently, and what was surprising to me, is that it is not the case. The Solar System was very dynamic and planets were moving around all over the place in the early years.

> "There will be Martians if we're to have a future. At some point we will be the Martians. That's clear to me"

Do you think there's a greater threat to Earth from humans, with climate change, or outside of Earth, for example an asteroid collision?
Ultimately, we feel small when we watch films about the Solar System and beyond. I think there's a sense in which we feel detached from nature, and that would be a mistake. Science is an attempt to understand nature, of which we're a part, and that's vital for our survival. So you mentioned one, which is the legitimate question we could ask: how do planetary atmospheres evolve? What we've found is that planetary atmospheres are rather fragile things in a sense, and they can evolve in response to quite small changes. We've seen that not only by measuring the Earth's atmosphere, and modelling it, but also trying to model Venus' atmosphere, in particular where we also deploy our climate models, and also Mars' atmosphere and how it lost its atmosphere, which is also a target for our climate models. Investigating the Solar System allows us to test our understanding of the Earth; that's the point, because we have different laboratories. So that's number one.

But number two, as you say, the threat of an asteroid strike, for example, is very real. It does happen. Carl Sagan - this is one of my favourite quotes... I always quote it - he said: "If the dinosaurs had a space programme, they'd still be around." But he was making a serious point that we do live in a challenging environment, and the more we understand about it, and the more we develop our technologies, it may allow us to mitigate some of these threats. This makes it more likely we are able to survive. So I think that's also important. That's not science fiction, it's a real issue.

What gaps do you think there are in our knowledge of the Solar System and where would you like to see visited next by human space probes?

The Planets

Brian Cox revisits the Solar System with new show *The Planets*, its debut episode appearing soon on BBC Two. The show explores not only the planets, moons and other objects that make up our cosmic community, but also their evolution. The history of the Solar System reveals how lucky Earth has been with its planetary siblings, and why it is so peculiar when compared to worlds hundreds and thousands of light years away in other planetary systems.

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The next big mission from NASA is the Europa Clipper. It's a Jupiter orbiter, but it's focused on [its moon] Europa. I think the big questions now are astrobiology, which we deal with in a couple of the other programmes in the series with the question: is there life, particularly on Mars and on some of the icy moons? That's what the Europa Clipper mission is designed to answer, and it's also designed to scope out landing sites on Europa and try and understand whether it may be possible to get something into the ocean below the icy surface.

I expect after the Europa Clipper, the next one after that would probably be a Titan mission. Titan is a planetary-sized moon with a very thick atmosphere. It has a liquid-water ocean below the surface, a long way down, and it has the most complex organic chemistry of another body other than the Earth in the Solar System. There is a plan to put what is essentially, a helicopter onto Titan in the form of a drone. That's great because the gravity of Titan is a ninth of Earth's gravity and the atmosphere is denser than Earth's, so you can fly anything around it.

I think astrobiology is going to be the focus of the next two big NASA missions. Beyond that we'd like to see orbiters around Neptune. There's a lot of pressure to put an orbiter around Neptune, but it's very, very difficult to do.

What are the ethical considerations in colonising Mars, a feat that Elon Musk hopes to accomplish?

It's a superb question. In a sense, if there's no life on Mars then I don't think the ethical consideration arises. But if there are microbes, and we think about this very carefully in terms of the places we land on Mars and the way we treat the spacecraft out there, we do not want to contaminate it with Earth microbes.

There's a scientific reason for that, which is that if there is life there, we'd like to see if there was a second genesis, or whether there was a single genesis on Earth or Mars, because we know organic material can be transferred between planets. So it ruins the science.

In terms of ethics, we can go into quite a deep, philosophical area I think. It's how important microbes are. Now, they're important scientifically, of course, but the 'Muskian view' - which is actually what's called the 'O'Neillian view, going all the way back to a famous author called [Gerard] O'Neill who wrote a great book called *The High Frontier* - the idea is that intelligent civilisations are extremely rare and valuable and cannot survive for very long on a single planet. So there's that philosophical trend which has been there since the 1950s, I think, or even before. It's the idea that we as a species need to see ourselves as a space-faring species that is part of the Solar System that has access to resources beyond the Earth.

I think we have to be very careful from a scientific perspective about damaging potential ecosystems on Mars. We are already extremely careful; it's called 'planetary protection' and we take it very seriously. But, at the same time, I don't think that can stop us from going to Mars. It is actually the only place we can go beyond Earth in any plausible scenario.

I say in the Mars episode, I actually make this case, I say that there may not have been Martians and we need to find out, but there will be Martians if we're to have a future. At some point we will be the Martians. That's clear to me, because we can't stay here forever. The point is that O'Neill and a man called Robert Zubrin, who Musk is very heavily influenced on, all make this point that the great challenge on Earth at the moment is to manage an expanding population. To manage a civilisation that requires new frontiers, both intellectually and physically, and is confined to a very small planet with a lot of pressure on the resources that are here. The Solar System contains essentially infinite resources - it's effectively unlimited.

What are your thoughts on exoplanet research and what it can tell us about the past and future of the Solar System?

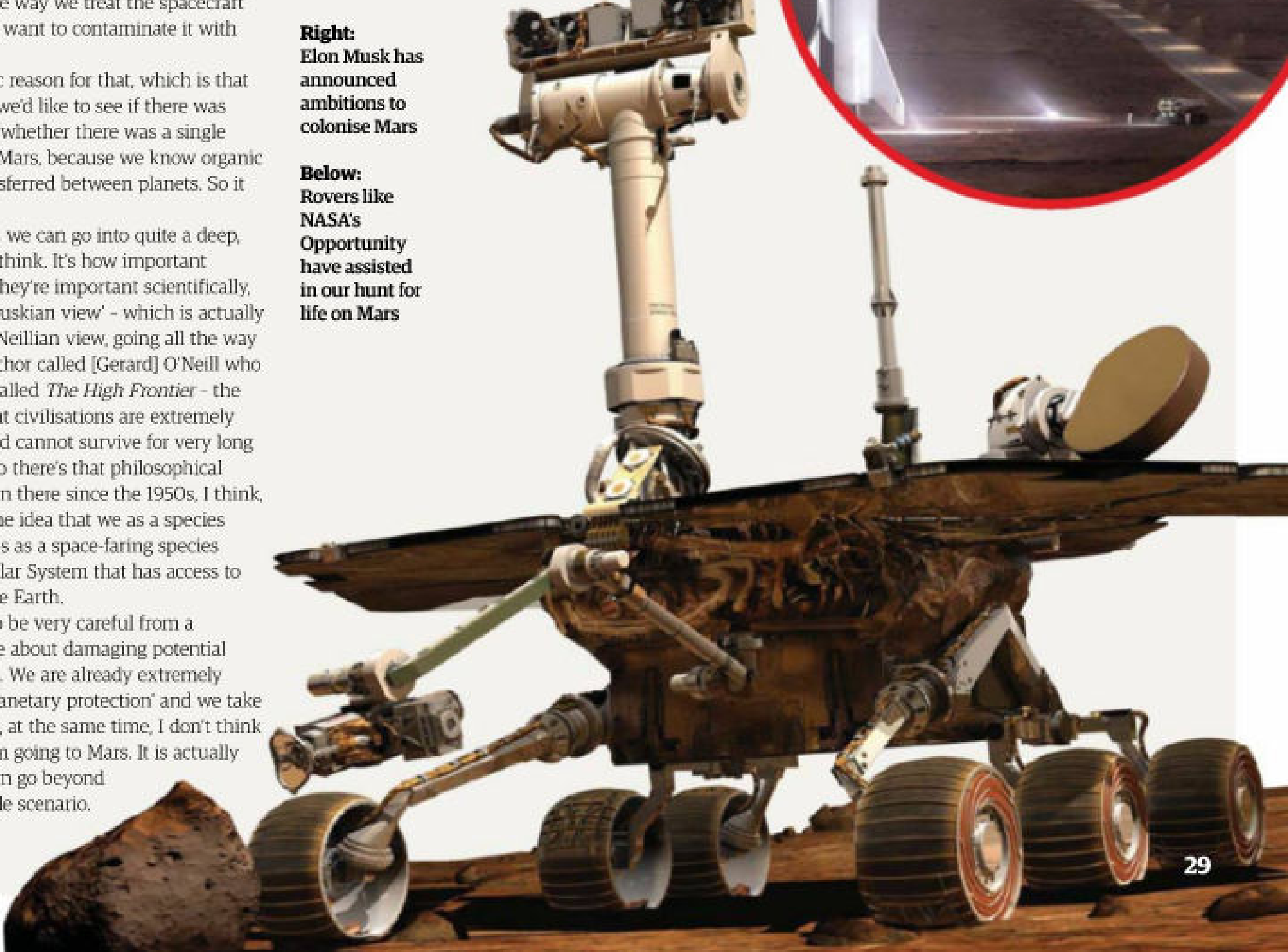
The great shock when we looked at other solar systems was that they were not arranged like ours. When I was at university, you tended to build theories that said the rocky planets form close to the Sun and the big gas giants form further out, and we had loads of plausible theories why that would be the case until we looked and saw that it was not the case in most other solar systems. And that's why I think one of the driving factors behind rather convoluted models, like the grand tack model, is because then you start to say, "If it's not obvious that the rocky planets form close to the star and the gas giants further out, why is our Solar System the way that it is?" And that's driven a lot of the modelling. So yes, it has had a profound effect.

Do you think it's a miracle that our planet exists?

The more we learn, the more remarkable it seems. You can be misled with that line of argument because there are a lot of things that have to happen to get the specifics, and you can go right back to little collisions with grains of dust in the formation of the Solar System, or actually, even the laws of nature themselves. We don't even know where the laws of nature came from.

So, in a way, it's empty of information to say we are lucky to be here. Even with each individual, think about the likelihood of you personally being here, what with your parents and grandparents. It's almost a miracle that each one of us exists as an individual. But what you do learn is that if you are just asking the generic questions about planets that could have an ecosystem that supports evolution by natural selection for billions of years, then you do find something valuable: the story of the Solar System. You look at it and think, "Well, actually, there are a lot of things that had to happen to keep this planet stable."

Right: Elon Musk has announced ambitions to colonise Mars



Below: Rovers like NASA's Opportunity have assisted in our hunt for life on Mars

TRITON HOPPER

NASA's proposed mission to Neptune's largest moon

While NASA's Europa Clipper mission gathers momentum for its upcoming adventure to Jupiter's icy moon in 2023, NASA is also preparing for another moon mission – one that will take humankind to Neptune's moon Triton.

Triton is the largest moon of Neptune and the seventh largest moon in the Solar System, but it is a bit of an oddball. Triton was first visited – and still, only – by NASA's Voyager 2 probe in 1989, and scientists found it to be very peculiar. For starters, it orbits in the opposite direction to the rotation of Neptune. Its surface looks young, with a lack of impact craters, and even exhibits geysers and winds, suggesting it is a geologically active body. These indicate that Triton is not a moon, but likely a world captured from the Kuiper Belt. Triton could actually be a mislabelled Kuiper Belt Object (KBO) captured by the gravity of our Solar System's furthest known planet. Triton is larger than the dwarf planet Pluto, and is visually similar to the dwarf world. This makes Triton an attractive target as it provides an opportunity to study a relatively nearby potential KBO that is also geologically active.

To successfully send the probe to Triton, astronomers want to utilise an eclectic combination of solar-electric propulsion and an aerocapture system, which would reduce the Hopper's velocity to allow it to enter an elliptical orbit around the celestial body. This journey would take roughly 12 years from Earth. This provides a quicker trip time compared to other options and these technologies are continuing to improve as time goes on.

> "Triton is the largest moon of Neptune and the seventh largest moon in the Solar System, but it is a bit of an oddball"

The aim of the mission is to land the Triton Hopper in the southern hemisphere of Triton which will eventually travel towards the equator over a two-year period, hopping once every 24 days. Although the project is only in its preliminary stages – having entered phase two in March 2018 which will continue to iron out the details on paper – the ideas being suggested are brilliantly creative and very efficient.

The gravity on Triton is roughly only eight per cent of Earth's gravity; this would mean that not as much propellant is needed to hop across the surface to examine the different terrain and atmosphere. The Hopper would use a radioisotope heat source to keep the probe from freezing in the dark, cold depths of the Solar System, but the space probe will also look to use this heat to mine and melt frozen nitrogen from the surface. This frozen nitrogen could replenish the fuel tank and means astronomers and engineers don't have to rely purely on the fuel they send with the mission. This will hopefully power jumps that reach a kilometre (0.6 miles) high and five kilometres (three miles) long, transporting the roughly-450 kilogram (992 pound) space probe across the surface.

Above: The difference in terrain between the equator and pole suggests Triton is geologically active

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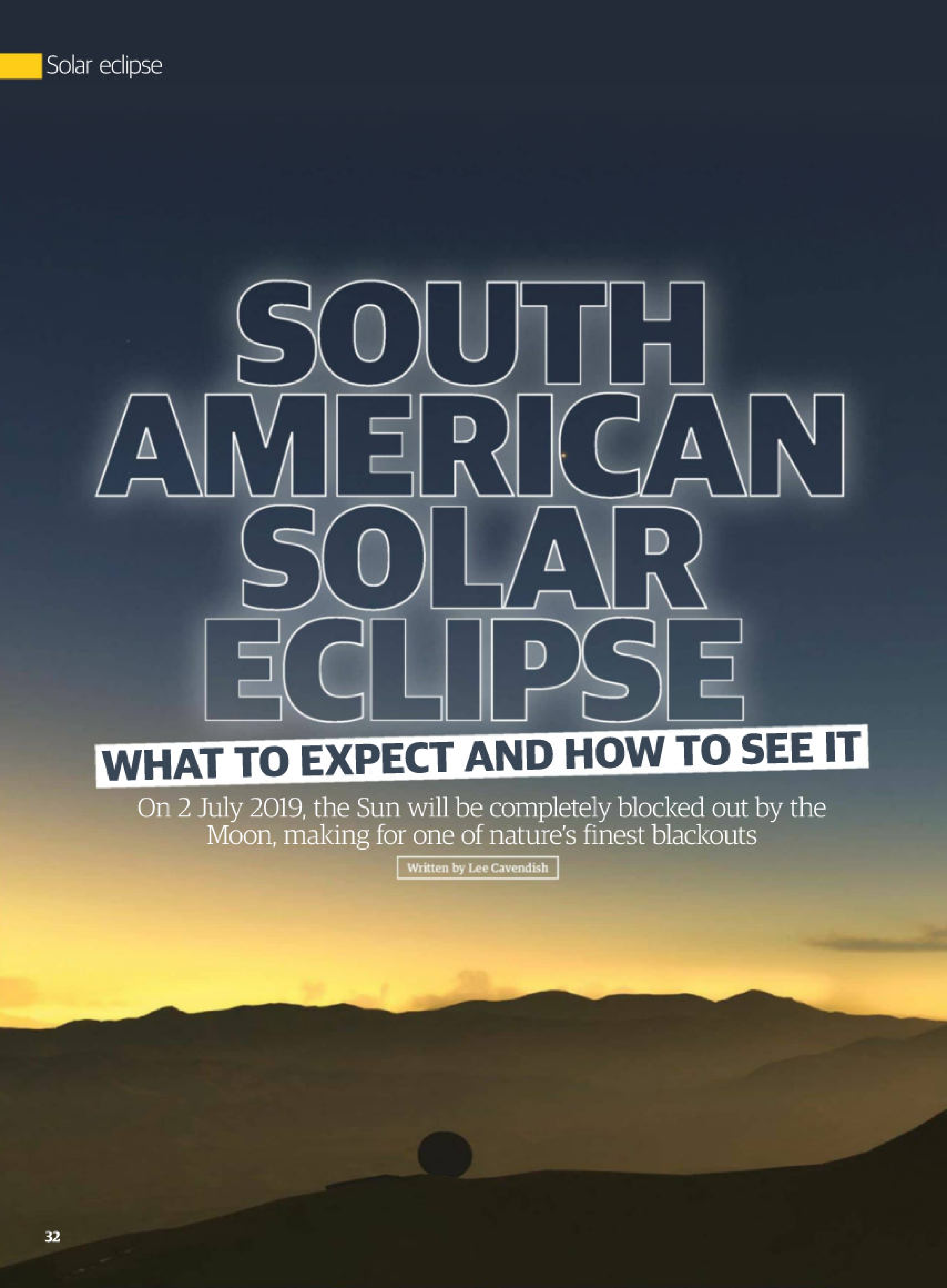


SOUTH AMERICAN SOLAR ECLIPSE

WHAT TO EXPECT AND HOW TO SEE IT

On 2 July 2019, the Sun will be completely blocked out by the Moon, making for one of nature's finest blackouts

Written by Lee Cavendish

© ESO

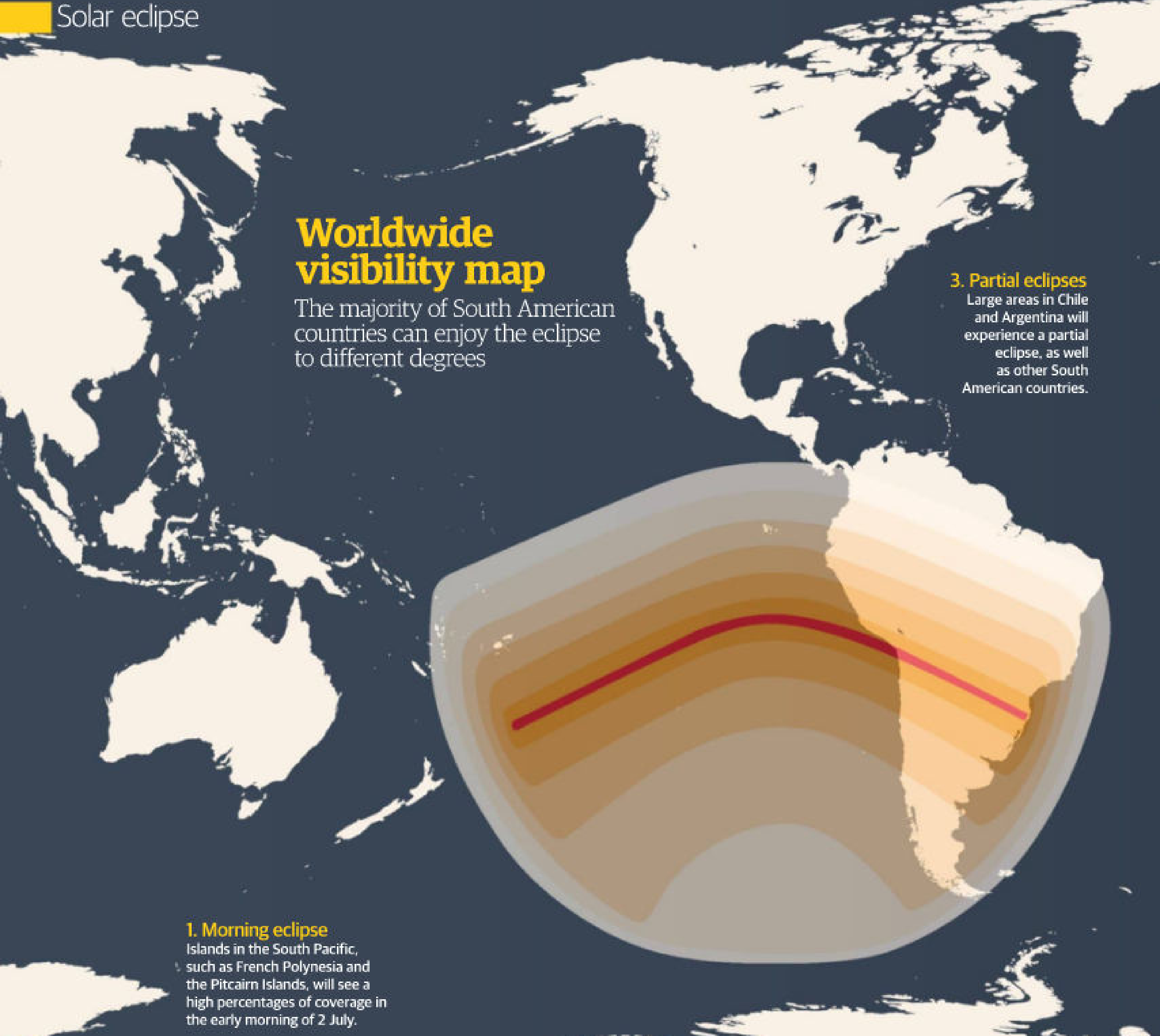
Blackouts aren't usually an event that people look forward to, but when a total solar eclipse occurs, people come from all over the world to embrace every second. Although there are lunar eclipses - where the Moon enters Earth's shadow, or 'umbra', behind the Sun - and planetary eclipses - normally associated with the transits of Venus and Mercury - nothing can beat a total solar eclipse.

On 2 July 2019 South America will host a total solar eclipse, which at 100 per cent totality - a term used when the Moon completely blocks out the Sun, or vice versa - will span 200 kilometres (125 miles) across the South Pacific Ocean, Chile and Argentina. Other countries in South America will be able to experience a partial eclipse, such as Paraguay, Bolivia, Brazil, Peru and Colombia.

Full eclipses are extremely rare as they require a new Moon, which then needs to cross paths with the Sun as it moves around the sky in what is also known as the ecliptic. Due to a celestial coincidence, the Sun and Moon are roughly the same size, which is approximately half a degree. To put that into comparison, that is about half the size of your little finger held at arms length away from you. When this event lines up, it leads to a brief period of a world without the Sun.

Worldwide visibility map

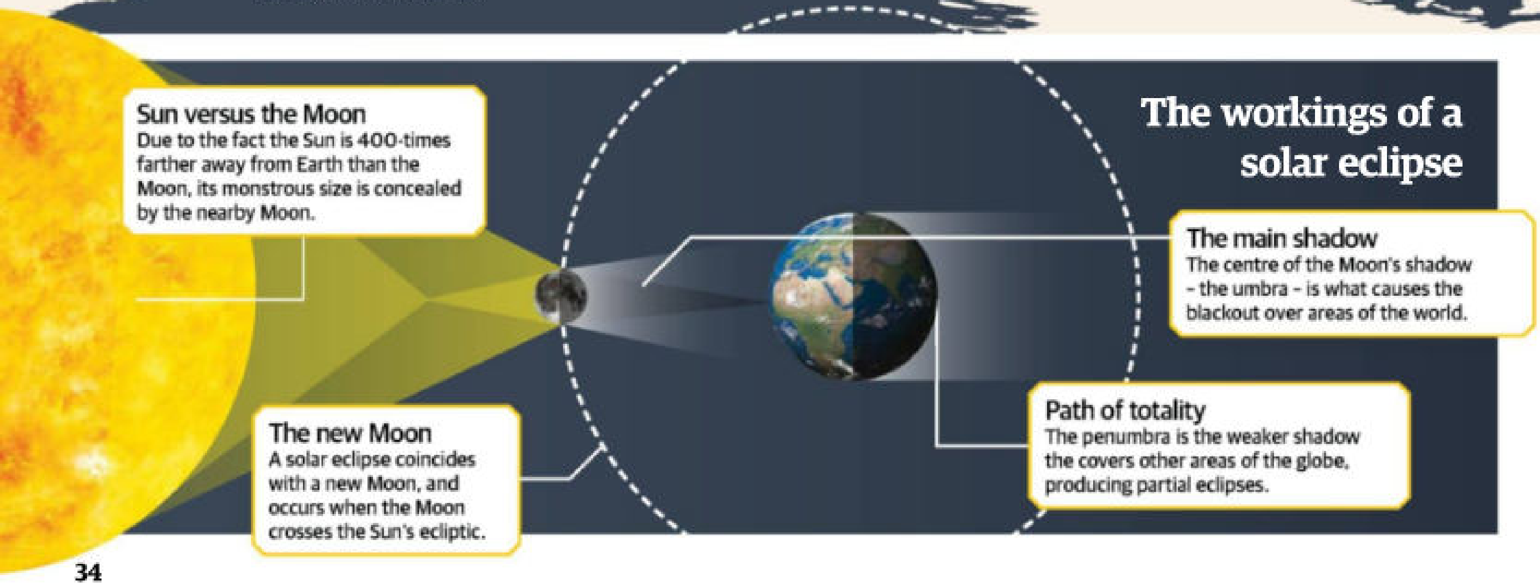
The majority of South American countries can enjoy the eclipse to different degrees



1. Morning eclipse
Islands in the South Pacific, such as French Polynesia and the Pitcairn Islands, will see a high percentages of coverage in the early morning of 2 July.

3. Partial eclipses
Large areas in Chile and Argentina will experience a partial eclipse, as well as other South American countries.

The workings of a solar eclipse



Sun versus the Moon
Due to the fact the Sun is 400-times farther away from Earth than the Moon, its monstrous size is concealed by the nearby Moon.

The new Moon
A solar eclipse coincides with a new Moon, and occurs when the Moon crosses the Sun's ecliptic.

The main shadow
The centre of the Moon's shadow - the umbra - is what causes the blackout over areas of the world.

Path of totality
The penumbra is the weaker shadow the covers other areas of the globe, producing partial eclipses.

4. End of the eclipse

The eclipse will finish with the Sun setting in eastern Argentina, just south of Buenos Aires.

2. Entering the mainland

The path of totality will first enter mainland South America in Chile. The best place to see it is La Serena.

August 2017 saw the solar eclipse dubbed 'The Great American Eclipse', its path of totality stretching from the West to the East Coast across the United States, as well as the Pacific and Atlantic Oceans. Almost two years later the world is about to bear witness to another eclipse that will not only create an amazing spectacle for general members of the public, but also provide scientists with an opportunity to study the most elusive and intriguing area of the Sun: its corona.

The eclipse will begin as a partial eclipse at 16:55 GMT (12:55 EDT) over the Pacific Ocean before totality will begin to cast a shadow on the land over Oeno Island – a British territory making up part of the Pitcairn Islands in the South Pacific Ocean – at 18:24 GMT (10:24 PST). From there it will travel southeast through La Serena in Chile and San Juan, Río Cuarto, Venado Tuerto, Junín and Pergamino in Argentina. It will just miss Buenos Aires, Argentina, and Montevideo, Uruguay, as it travels south of these cities. The end of totality will reach the Atlantic Ocean just before sunset at 20:40 GMT (17:40 ART).

The south of Uruguay and the capital of Chile, Santiago, can still experience a large majority of the Sun being blocked out, at least 90 per cent, in fact. A partial eclipse is caused when the Moon creates a 'penumbral shadow', casting a less intense shadow on Earth's surface. Places as far as French Polynesia, south Peru and Bolivia could even see at least 50 per cent coverage. However, it is the 100 per cent totality that produces the most awe-inspiring views, and that is why people will flock towards its path through Chile and Argentina.

Top: Special eclipse glasses allow safe viewing of the Sun

Above: The Sun's corona is only visible from Earth during a total solar eclipse

Top five destinations to see the eclipse

La Serena, Chile

Partial eclipse begins
17:22 CLT (19:22 GMT)
Totality
16:38 CLT (20:39 GMT)
Duration of totality
2 minutes 18 seconds
Partial solar eclipse ends
17:46 CLT (21:46 GMT)
Amount of eclipse
100 per cent

La Silla Observatory

Partial eclipse begins
15:23 CLT (19:23 GMT)
Totality
16:39 CLT (20:39 GMT)
Duration of totality
2 minutes 25 seconds
Partial solar eclipse ends
17:47 CLT (21:47 GMT)
Amount of eclipse
100 per cent

San Juan, Argentina

Partial eclipse begins
16:26 ART (19:26 GMT)
Totality
17:40 ART (20:40 GMT)
Duration of totality
36 seconds
Partial solar eclipse ends
18:42 ART (21:42 GMT)
Amount of eclipse
100 per cent

Río Cuarto, Córdoba, Argentina

Partial eclipse begins
16:30 ART (19:30 GMT)
Totality
17:41 ART (20:41 GMT)
Duration of totality
1 minute 59 seconds
Partial solar eclipse ends
Sunset
Amount of eclipse
100 per cent

Buenos Aires, Argentina

Partial eclipse begins
16:36 ART (19:36 GMT)
Totality
17:44 ART (20:44 GMT)
Duration of totality
None
Partial solar eclipse ends
Sunset
Amount of eclipse
99.7 per cent

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Weather is a factor that must always be taken into account when planning an outdoor observing trip such as this one. Of course, cloud coverage is something that simply can't be determined far in advance, but it is worth taking into account that South America will be experiencing austral winter. This means the Andean region has the best chances of viewing at high altitudes, as it will hopefully have incredibly clear skies and low humidity. Although, as the eclipse moves towards the horizon towards eastern Argentina, clouds may interfere with the view of a low-altitude Sun.

Safety when observing the Sun is key. The light released by the Sun can be very damaging to your eyes, and it is important to emphasise that the eclipse can only be viewed with the naked eye during complete totality. Before and after the eclipse, viewing must be done with the help of certified-safe solar eclipse glasses, solar filters that can be attached onto binoculars or a telescope or even a colander, as it can project the light, and therefore the light crescents, onto a sheet of white paper.

Those fleeting moments of totality are marvellous as darkness takes over, providing the rare opportunity to observe the white-hot corona emanating from the outer region of the Sun. Just as the eclipse occurs, there is also the chance to see the famous diamond ring, a term given to the moment when the Sun's last light is gleaming as a faint ring surrounding the Moon.

The European Southern Observatory (ESO) has prepared an event at its La Silla Observatory in the Atacama Desert in Chile, just north of La Serena. With a host of diligent telescopes, the organisation has opened its doors to the public to watch the solar eclipse, as it falls in the path of totality. People will be able to watch a total eclipse of the Sun, along with other activities, the observatory flaunting the fact that its high altitude of 2,400 metres (7,900 feet) means the solar eclipse will bring out an array of bright stars and planets around the eclipse, including Mars, Betelgeuse, Procyon, Sirius and a few others.

You don't need to be in the path of totality to observe such an amazing occasion, either, as different organisations are preparing live streams of the event to broadcast around the world. The ESO will have a stream available closer to the occasion, as will the Slooh Observatory, Exploratorium and similar YouTube live-streaming channels.

Left: Full totality will be seen from Río Cuarto in Argentina

Below: A total eclipse creates the illusion of a diamond ring

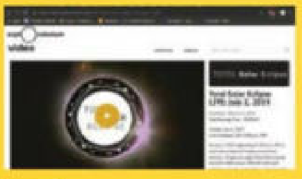
> "Weather is a factor that must always be taken into account when planning an outdoor observing trip such as this one"

Watching the eclipse from anywhere in the world

Exploratorium

exploratorium.edu/eclipse

Starting at 13:00 PDT (20:00 GMT), Exploratorium will broadcast from La Serena, Chile. The stream will be available for free on its website and apps.



ESO

eso.org/live

Along with its publicly available event, the ESO will be broadcasting the eclipse live from the La Silla Observatory on its website.

Time and Date

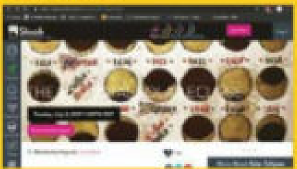
timeanddate.com/live/

This website not only offers a livestream, but will send you reminders. It has an iOS app and a 3D coverage map with all the necessary information.

Slooh Observatory

slooh.com/shows/event-details/623

For membership holders, Slooh astronomer Paul Cox and astrophysicist Dr Paige Godfrey will commentate on a stream of the solar eclipse.



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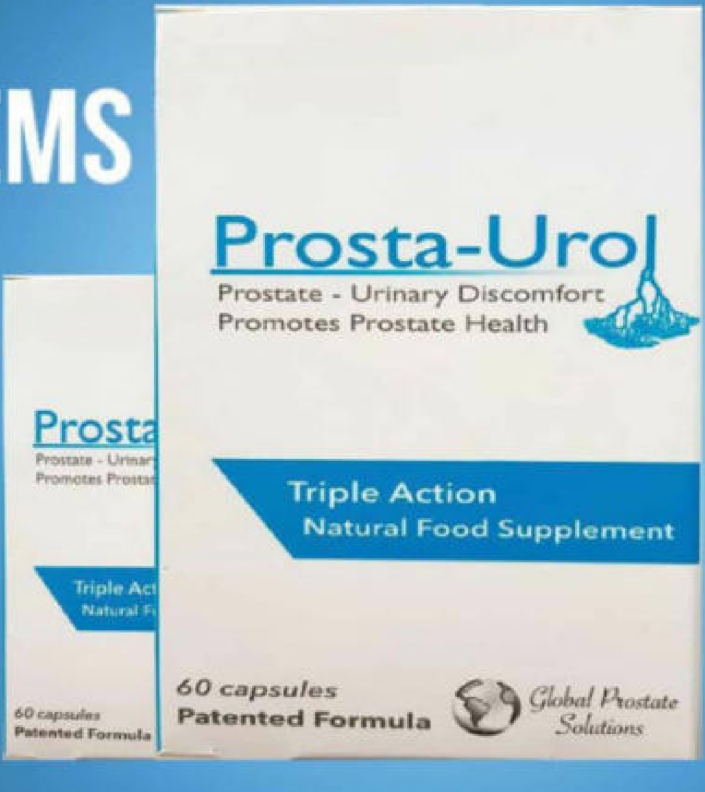

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MYSTERIES OF THE UNIVERSE

YURI GAGARIN

WAS HE REALLY THE FIRST MAN IN SPACE?

Before the cosmonaut orbited the Earth, rumours abounded that someone else already had

Reported by David Crookes

Everybody knows that Neil Armstrong was the first person to set foot on the Moon. Most people are also aware that he wasn't the first to go into space. After all, Alan Shepard paved the way for American astronauts on 5 May 1961, while Soviet cosmonaut Yuri Gagarin stole a march by rocketing into space a few weeks earlier on 12 April. Or did he?

Today Gagarin's name is cemented in the record books, and he instantly became a national hero across the Soviet Union. Presented as a triumph of the fiercely fought Space Race against the US, the 27 year old, who had been chosen just three days before the mission, spent 108 minutes in space, orbited the Earth and returned fit and well following a drama-filled flight.

And yet, before he even embarked on his journey skywards, doubt was seeded in many a person's mind. For rumours had surfaced that the Soviets had successfully launched a man into space before Gagarin set foot in Vostok 1, and the talk was that

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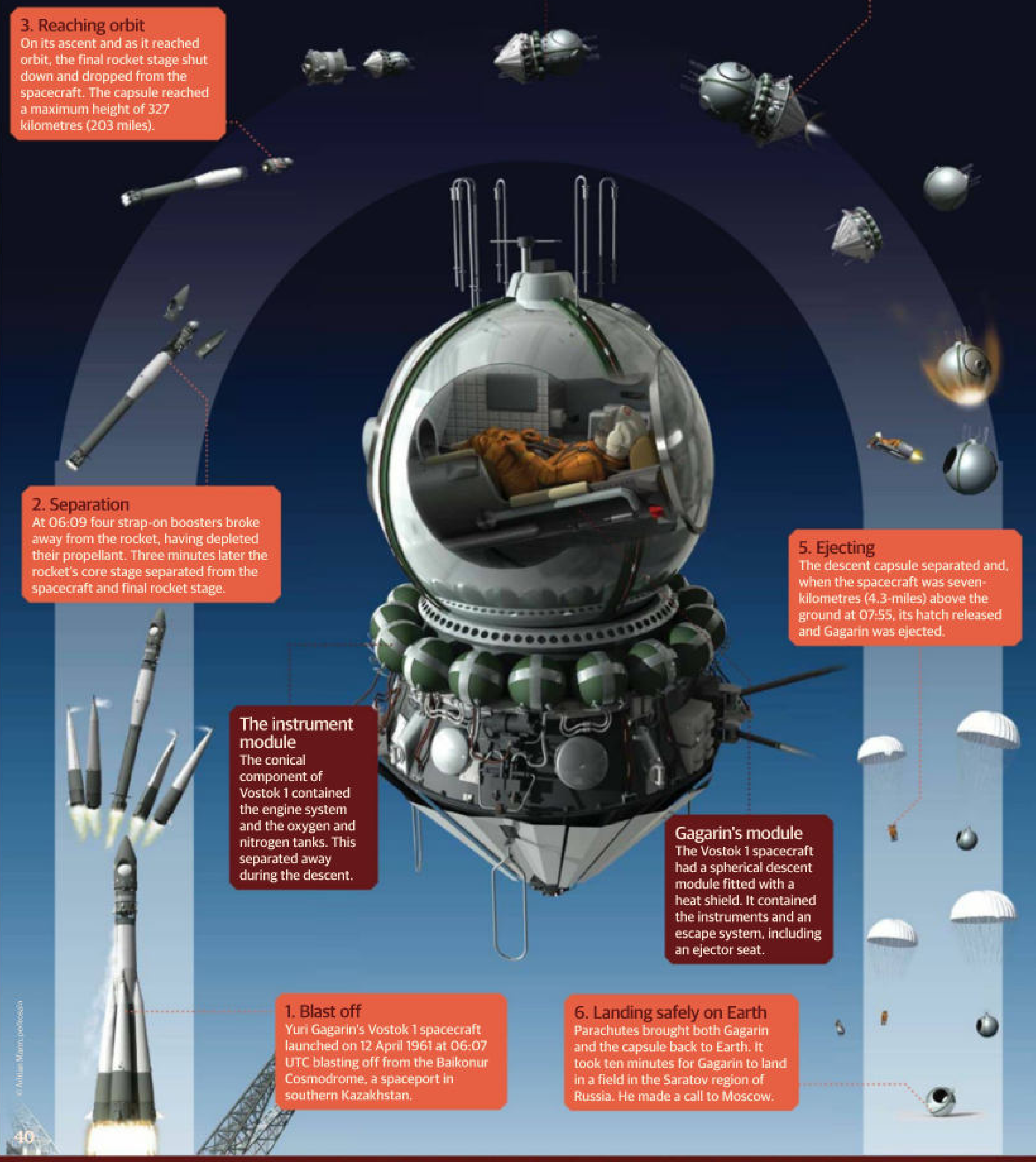
Yuri's flight path

Gagarin was calm prior to his ascent into space, despite being the first human to do so



Eye on the world

A large window in the capsule ensured Gagarin was able to see the outer surroundings of space. It was covered by a payload shroud during the launch.

4. Revolving around the Earth

Gagarin was able to make a single revolution of Earth on a journey of 40,868.6 kilometres (25,394.8 miles), which took 108 minutes.

3. Reaching orbit

On its ascent and as it reached orbit, the final rocket stage shut down and dropped from the spacecraft. The capsule reached a maximum height of 327 kilometres (203 miles).

2. Separation

At 06:09 four strap-on boosters broke away from the rocket, having depleted their propellant. Three minutes later the rocket's core stage separated from the spacecraft and final rocket stage.

5. Ejecting

The descent capsule separated and, when the spacecraft was seven-kilometres (4.3-miles) above the ground at 07:55, its hatch released and Gagarin was ejected.

The instrument module

The conical component of Vostok 1 contained the engine system and the oxygen and nitrogen tanks. This separated away during the descent.

Gagarin's module

The Vostok 1 spacecraft had a spherical descent module fitted with a heat shield. It contained the instruments and an escape system, including an ejector seat.

1. Blast off

Yuri Gagarin's Vostok 1 spacecraft launched on 12 April 1961 at 06:07 UTC blasting off from the Baikonur Cosmodrome, a spaceport in southern Kazakhstan.

6. Landing safely on Earth

Parachutes brought both Gagarin and the capsule back to Earth. It took ten minutes for Gagarin to land in a field in the Saratov region of Russia. He made a call to Moscow.

© Adrian Mann; pedrosa

one cosmonaut had done so on 7 April, just five days earlier.

Dennis Ogden, the Moscow-based correspondent for the British Communist Party newspaper, *Daily Worker*, reported as such, his story splashed across the publication's front page with the headline: 'The First Man In Space'. It informed readers that the spaceman - "the test-pilot son of a top-ranking aircraft designer" - was "back alive, but suffering from [the] effects of his flight". Gagarin's feet hadn't even left the ground when the paper hit the newsstands, and it caused something of a stir. The first whispers of a conspiracy theory which has continued to this day. The Soviet Union denied the reports and instead alerted the press to Gagarin's subsequent feat. Ogden also reported this, his article again making the splash as he wrote of a "hero's welcome" and a Soviet Union "wild with joy at [the] first trip outside this world".

Ogden's article could have been seen as something akin to a correction; confirmation that he was initially wrong about the flight on 7 April. But then French journalist Eduard Bobrovsky followed up on Ogden's claims and pointed to the man in question as being an accomplished test pilot called Vladimir Ilyushin, while also stating the flight actually took place on 25 March. Trouble is, this mission had - according to the press sources - not gone quite as well as planned. That is why, it has long since been claimed, Ilyushin's feat was cast aside in favour of Gagarin's successful launch and landing.

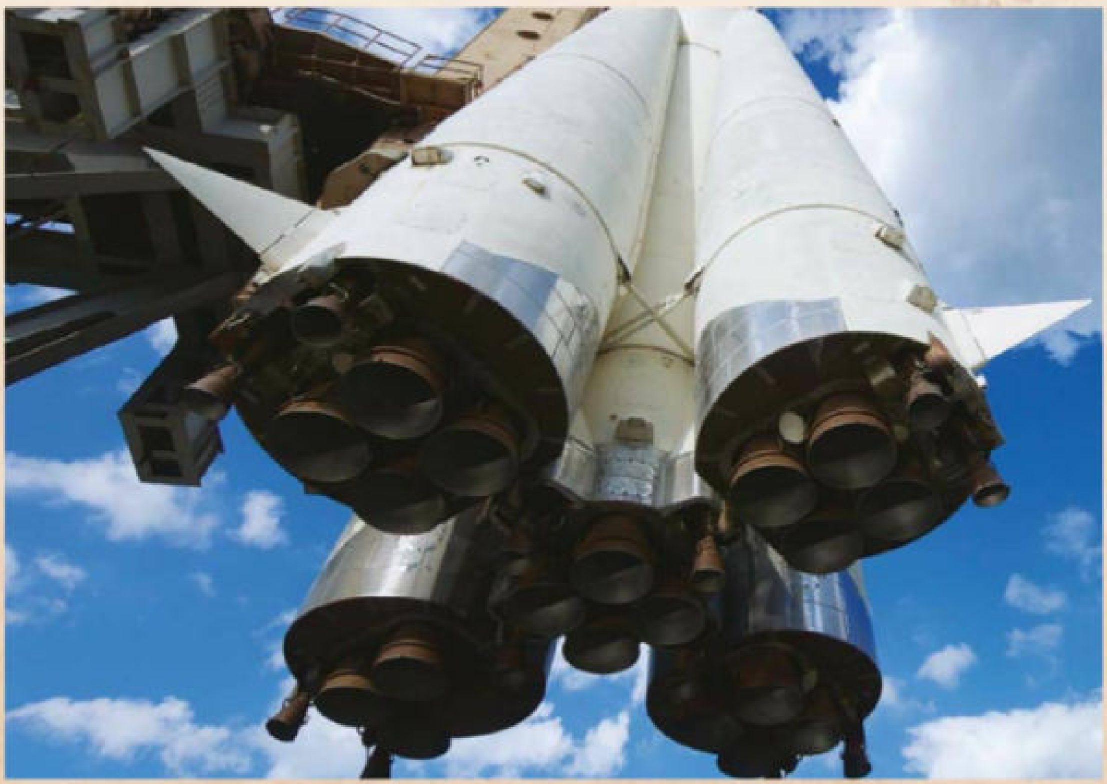
Ilyushin was a Soviet general and a test pilot of high standing. He had broken many a speed and altitude record and his father was influential, having designed and built Second World War fighters and bombers. Ilyushin senior had also earned himself a place in government. To that end, his son would have been seen as the perfect person to send into space, his penchant for risk taking such that the then-34-year-old pilot would have surely relished the task. And so the story went that his journey outwards on board his spaceship was fine but, after three supposed orbits, Ilyushin's return went awry. Apparently his landing was off-course, causing him physical harm and mental anguish. There was even a suggestion that the accident had put him into a coma.

"Rumours surfaced that the Soviets had successfully launched a man into space before Gagarin"

"The space vessel reportedly was recovered where expected, but Ilyushin was mentally unbalanced and is unconscious in a Moscow hospital," said a report in *The Spokesman Review* about the journalist's claims on 22 April 1961. The article added that Bobrovsky said his information came from reliable sources that he could not name and that Russian officers denied the report. Indeed, the Soviet Union claimed Ilyushin was in hospital being treated for injuries he had received in a car accident.

The Soviets were not the only ones blinking with disbelief at this. Even the Americans did not believe the journalists' claims. Indeed, Pierre Salinger, the press secretary to the White House at the time, told

Below: The Vostok-K (8K72K) rocket carried Gagarin and the Vostok 1 spacecraft to orbital altitude



The lost cosmonauts?

Aleksei Ledovsky

1957

A top-ranking communist from Czechoslovakia claimed Ledovsky had died, having been launched in a converted R-5A rocket on a suborbital flight from Kapustin Yar rocket base. There is no evidence of a manned Soviet suborbital spaceflight.

Andrei Mikov

1959

Another said to have died on a suborbital flight, as reported by the Italian news agency Continentale. This was stated as having happened a year after cosmonaut Serenti Shiborin was killed in the same way.

Two, unknown

1961

The Italian Judica-Cordiglia brothers claimed to have picked up the sound of a dying, unconscious man, as well as a failing human heartbeat, with the suggestion that these were from two Soviets who had suffered a failed re-entry.

Unknown

1961

It is suggested that a manned Vostok orbital launch took place on 16 May 1961 and that, following 17 orbits around Earth, depletion of the spacecraft's oxygen supplies caused the cosmonaut to suffocate.

Pyotr Dolgov

1962

The story is that Dolgov died during a parachute jump at high altitude from a Volga balloon gondola on 1 November 1962 after hitting a part of the gondola, depressurising his suit. There have been reports he actually perished in a failed Vostok flight.

The theories

Vladimir Ilyushin circled Earth three times

Dennis Ogden suggested a cosmonaut had successfully completed a manned spaceflight on 7 April 1961 but it had left him incapacitated, forcing Russia to find someone else to face the public.

Vladimir Ilyushin crashed in China

Further embellishments claimed Ilyushin had crashed in China and was not only injured but in the hands of the Chinese, who refused to release him.

Vladimir Ilyushin was an obvious choice

One of the reasons why Ilyushin's name crops up in relation to this conspiracy theory is that his background was conducive to a space mission. He was an accomplished test pilot.

Yuri Gagarin was the first person in space

Ilyushin is thought to have been involved in a car accident and he is not understood to have been in the cosmonaut group. For that reason, he never did go into space.

Below: The general consensus is that Yuri Gagarin was the first to orbit the Earth

Below right: The Vostok 1 capsule used by Yuri Gagarin, which is on display outside of Moscow at the RKK Energiya museum

reporters that there was no evidence of a flight on 7 April and, we have to assume, nothing to have raised suspicion in March either. NORAD space tracking stations, it transpired, had not picked up on anything, and the US was not about to leap in and heap embarrassment on the Soviet Union without proof.

And yet, even this wasn't enough to completely quell suspicion. Some journalists reckoned the claims of a car crash were a mere cover story, and it certainly wasn't beyond the wildest of imaginations to believe the Soviets would seek to bury a mistake, since it had been done so many times in the past. What's more, in the framework of the Space Race, conspiracists could surmise there was a valid reason for trying to bury such a failure: the Soviets would constantly pull out all the stops to present communism as the superior ideology.

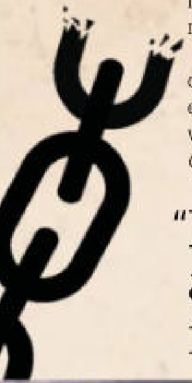
But is that, together with unknown journalistic sources, reason enough to believe that Gagarin's place in history was not quite what it was? Ogden would later claim that he saw a photograph of Ilyushin wearing space gear at the time of the supposed flight, but it has never subsequently surfaced. Meanwhile, Ilyushin himself - who died in 2010, aged 82 - never confessed to having flown into space. He lived to tell the claimed tale, but notably did not.

What we have seen, however, are rumours continuing to swirl long after the event, and they've even been fleshed out. One of the most notable was a 52-minute documentary in 1999 called *The Cosmonaut Cover-Up*, released by Global Science Productions and directed by Dr Elliott Haimoff who, in the following year, also helmed *Vladimir Ilyushin: The Real First Man in Space*.

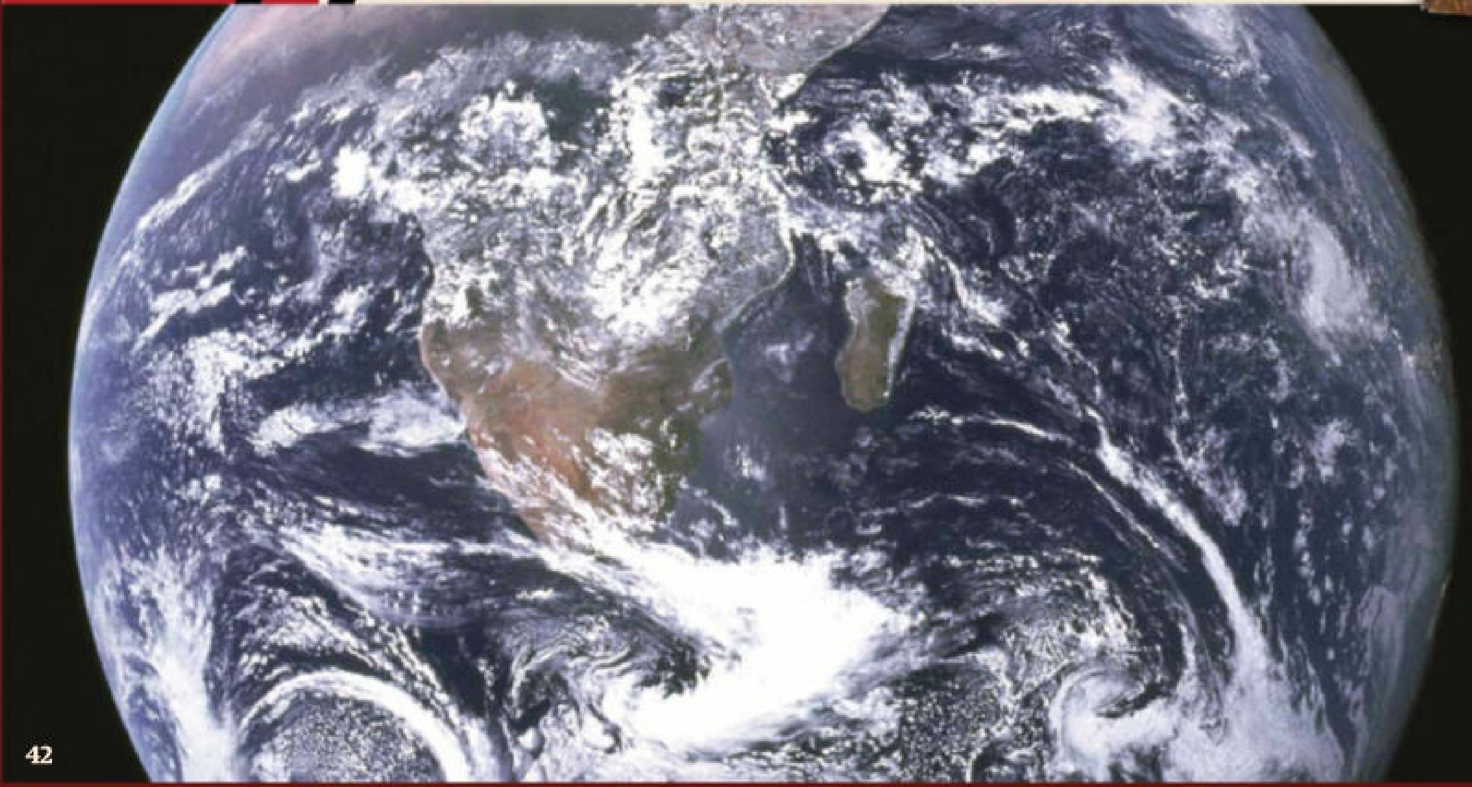
Widely broadcast, it claimed Ilyushin had failed to eject from his capsule, crashed into China and, after being captured, was eventually handed back to the USSR in 1962. The documentary makers said Ilyushin wouldn't talk about the alleged incidents on camera and preferred to maintain his secrecy. But was Ilyushin so fearful that, in verifying such claims, he would open himself up to a world in which he did not wish to boldly go? Given that the documentary was being made a number of years after the collapse of the Soviet Union, when secrets were finally being divulged and historical events were being flung open, you would suspect not.

In fact, the Soviets began to open up well before the USSR ceased to be. In 1980 the West finally learned of the death of Valentin Bondarenko, who died ten days into a 15-day low-pressure endurance experiment in Moscow in 1961 when fire broke out, even though they had removed his image from an official subsequent training photograph. It took longer to tell the world of a major launchpad accident which took place on 24 October 1960 and officially killed 78, as eventually revealed to the rest of the world in 1989. There's talk of Gagarin being used for propaganda, but of all the confessions and documents seen since the Soviet Union collapsed, Ilyushin has never featured.

And yet there have been some peculiar pieces of 'evidence'. Two Italian former



> "Ilyushin himself - who died in 2010, aged 82 - never confessed to having flown into space"

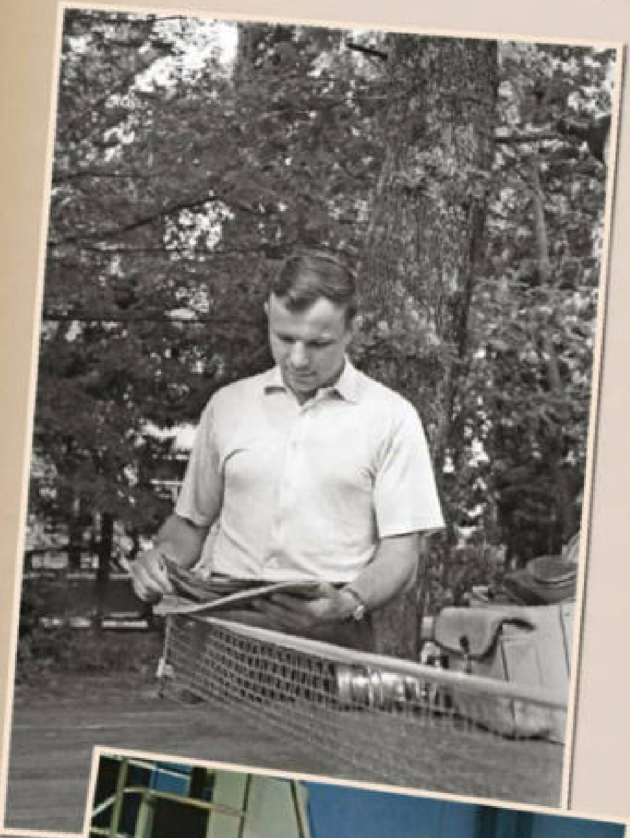


Yuri Gagarin's scrapbook

Getting ready for space requires great dedication, as shown in these photos of the first man to go

Left Wearing his overalls and oxygen mask, the effects of space are tested on Yuri Gagarin's body in 1958

Right Taking some time out to relax during his training, this image was taken following his journey back to Earth



Right Yuri Gagarin is pictured (second left) with a cosmonaut training group, checking out the space equipment in 1960

Left Yuri Gagarin assumes his lying down position, as he would inside the space capsule

Right Yuri Gagarin trains in the Vostok spacecraft in November 1960, five months before his history-making flight

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amateur radio operators, Achille and Giovanni Judica-Cordiglia, claimed to have recorded audio from an orbiting capsule in the days before Gagarin made his flight, and it was actually the fourth slice of startling audio released by the pair. The first was from May 1960 of a manned spacecraft reportedly going off-course; the second in November that year of an SOS Morse code from a trouble spacecraft leaving Earth's orbit and, most chillingly, a third in 1961 of a cosmonaut apparently suffocating to death. Should these be hard-and-fast evidence of spaceflights, then we would have to say that not only was Gagarin not the first person into space, Ilyushin was perhaps not first either. But given the supposition was that everyone involved in those three recordings had died, discovering the truth has been even more difficult. And yet theories still mount up.

Indeed, what could we make of claims by Mikhail Rudenko, a former Soviet senior engineer and experimenter with Experimental Design Office 456, who in 2001 told the Russian internet news website **pravda.ru**, formed in 1999 by members of the editorial staff of the oldest Soviet paper *Pravda*, that cosmonauts had been sent into space in 1957, 1958 and 1959.

"All three pilots died during the flights and their names were never officially published," he is quoted as saying, having explained that the pilots involved were called Ledovskikh, Shaborin and Mitkov and took part in sub-orbital flights. "The cosmonauts were to reach space heights in the highest point of such an orbit and then return to the Earth," he added. But considering *Pravda* has also run with headlines such as 'Aliens forced Americans out from the Moon' and 'Alien and human skulls found on Mars', it's a tough call!

Harder still to determine is Ilyushin's location in March and April 1961. The Soviets didn't help themselves in this regard either because they couldn't give a straight answer about the reason why he was seen to be injured - pinned down

Sequence of events

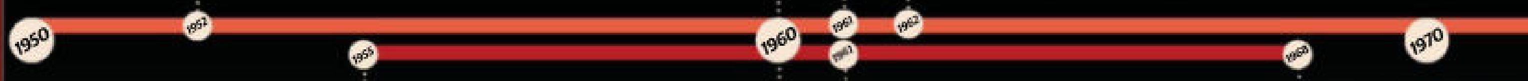
What's thought to have happened
What actually happened

Vladimir Ilyushin becomes a Soviet test pilot
Born to the Soviet aircraft designer Sergei Vladimirovich Ilyushin, Vladimir Ilyushin fulfilled his dream of wanting to become a test pilot of the best Russian aircraft.

He is made a Hero of the Soviet Union
Having built a reputation as a pilot, Ilyushin broke records, bringing him to the attention of the Soviet space programme.

Ilyushin heads into space
Newspaper reports suggested he had flown into space in secret on 7 April 1961. It was later claimed a spacecraft failure saw him land in China.

Yuri Gagarin named as the first man in space
On 12 April 1961, Yuri Gagarin completed his flight and the Soviets named him – not Ilyushin – as the first man to journey into space.



Yuri Gagarin enters flight training
Yuri Gagarin enrols at the Orenburg Pilot School and gains his pilot wings in a MiG-15. He became a senior lieutenant in November 1959.

Chosen as a prospective cosmonaut
Having excelled, Yuri Gagarin is picked with 19 other pilots during a secret selection process to find cosmonauts. He is chosen for elite training.

Picked to fly into space
His progress was so good that he and Gherman Titov were selected for the first launch. It also helped that he could fit in the Vostok capsule.

> "Supposing Russia had suffered such terrible space attempts, would it really have announced Gagarin's flight?"

to that car crash – or when it actually took place. Neither could they offer up a suitable explanation for why he might have been in China. They also went as far as to say he was never actually a cosmonaut and, indeed, it would appear that he wasn't in the original cosmonaut team. No memoirs or declassified information put him there.

Yet it's also difficult to corroborate the Judica-Cordiglia recordings with any data from official sources. Listening stations did not pick up on what they claimed to have committed to tape, and radio astronomer Bernard Lovell, who established the Jodrell Bank Observatory in Cheshire, England, dismissed claims of earlier Russian manned space attempts in 1963. Even that, however, isn't as clear cut as it sounds.

Lovell paid visits to Russia around this time, and there have even been allegations that he was brainwashed. He fell ill that year following such a trip, and the UK Ministry of Defence said it might have been due to an attempt to remove his memory of a Soviet offer to build a telescope facility in the USSR. His son says he was merely ill from exhaustion, and that sounds more plausible.

Besides, supposing Russia had suffered such terrible space attempts which resulted in deaths and crashes, would it really have announced Gagarin's flight in the way it did? As James E. Oberg points out in a 1975 article he wrote in *Space World* magazine, the Russian news agency TASS – frequently used as a front organisation by the Soviet intelligence agency – released its first bulletin while Gagarin was still in-flight. If it was worried about the potential for bad news, wouldn't it have been better to wait until the mission was over and Gagarin's feet were firmly back on the ground, rather than risk Gagarin's spacecraft hitting the same problems as the one claimed to have taken place just days before?

Maybe we will never know. As we've mentioned, the two men who would have been directly involved are not around any more – Gagarin was killed when the MiG-15 training jet he was piloting crashed on 27 March 1968 when he was 34. Given the evidence that has been made available, the smart money remains on Gagarin having been the first person on a manned spaceflight. Sure, Russian space history can be murky and difficult to pick apart, but in truth there is no real reason to lie in instances such as this.

Right: The 1981 ruble coin issued to commemorate the 20th anniversary of Gagarin's space flight

Captured and then released by the Chinese

Ilyushin was supposedly captured by the Chinese and held for a year. This is why, the theory goes, Ilyushin was not named by the Soviets.

Yuri Gagarin died in a psychiatric ward

Such was the burden on Yuri Gagarin's shoulders, he is said to have buckled. Sent to a secret psychiatric ward, he is claimed to have died in 1990.

1980

1990

Launches as the first man into space

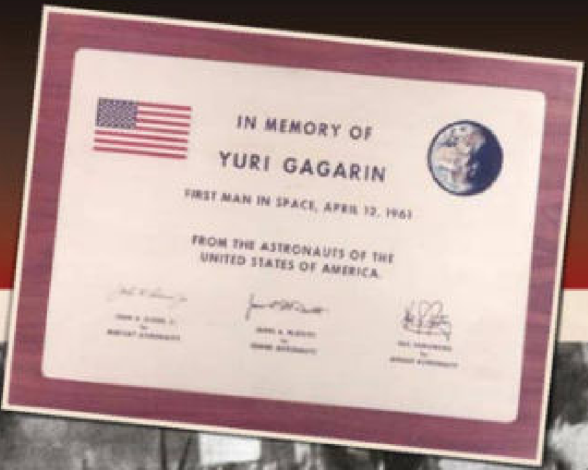
On the morning of 12 April 1961, Yuri Gagarin went to space and was in flight for one hour and 48 minutes, safely returning to Earth.

Becomes an international celebrity

Russia had brought attention to his feat while he was still in the air, and he became an instant hero. Vostok 1 was his only spaceflight.

Yuri Gagarin dies in crash

Yuri Gagarin was piloting a MiG-15 training jet on 27 March 1968, but it crashed. He sadly died that day, aged 34.



IN MEMORY OF

YURI GAGARIN

FIRST MAN IN SPACE, APRIL 12, 1961

FROM THE ASTRONAUTS OF THE
UNITED STATES OF AMERICA

© NC Collections / Alamy Stock Photo; SPUTNIK / Alamy Stock Photo; Adrian Mann; alldayru.com

Below: Yuri Gagarin was hailed a hero upon his return from space, pictured here being given a huge reception in Warsaw, Poland

EARTH FROM SPACE

ESA's Copernicus programme controls satellites around the globe, keeping a keen eye on our planet and producing stunning bird's-eye shots in the process

1 Bering Strait

The Copernicus Sentinel-1 satellite captured three radar scans of the Bering Strait and assigned them each a colour: blue, red and green. Combing these images shows how the sea ice varied over the four week period. This region connects the Pacific and Arctic oceans between Alaska and Russia, and the radar images were able to pierce through the clouds, very important for observations in a cloud-heavy winter period.

2 Alaska

Alaska is an environment being heavily affected by climate change. Copernicus has been watching over the US' most northern state, and in this instance the Copernicus Sentinel-2B satellite has been watching over the Columbia Glacier. This glacier has been hit hard by climate change over the last 30 years, and has been shown to have retreated more than 20 kilometres (12 miles). It has shockingly lost half of its volume and thickness.

3 The Netherlands

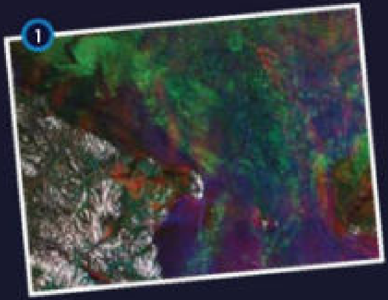
Amsterdam is peppered in canals that constitute over 100 kilometres (60 miles) of the region. There are two important reasons to monitor Amsterdam using satellites: firstly, to observe urban expansion into the surrounding wildlife habitats. Secondly, Amsterdam lies two metres (seven feet) below sea level and is susceptible to flooding. With the increase in sea levels, this is a danger that must be monitored for safety of the residents.

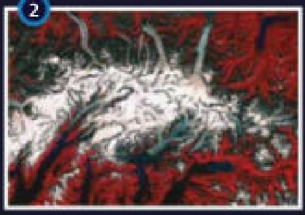
4 Peru

Bleeding surrounds the Chachani mountain in Peru. It is one of the tallest mountains near the city Arequipa. The red ring that surrounds the mountain was created with Copernicus' false-colour image and shows the land's vegetation, with different tones equating to different vegetation types in its annual cycle. Also surrounding Chachani is Arequipa's airport – at the bottom of the image – and three volcanoes.

5 Uruguay

It almost looks like an abstract painting, but it is actually the brown sediment-rich Uruguay River that divides its namesake country and Argentina. The wetland systems are a hub for exotic wildlife, including 130 species of fish, 14 species of amphibian, 104 species of bird and 15 species of mammal. A watchful eye must be kept on this rare haven to make sure the ever-changing world doesn't damage this environment.





6 Sicily

Copernicus has also focused on Sicily, Italy, and the two main Aegadian Islands – Favignana and Levanzo – with its near-infrared capabilities. This camera channel emphasises the vegetation, which is shown in the overwhelming red, but the bright turquoise colours represent salt marshes. These areas have shallow sea waters, windy coasts and abundant sunshine, which make for prime salt production.

7 The Alps

This mountain range stretches roughly 1,200 kilometres (750 miles) over eight different countries. France, Monaco, Italy, Switzerland, Liechtenstein, Germany, Austria and Slovenia all have a part of the Alps within, and approximately 20 million people reside within their confines. This true-colour image shows the snowy-white head of the Alps in all its glory, with very little cloud coverage in the south of France.

8 Kenya

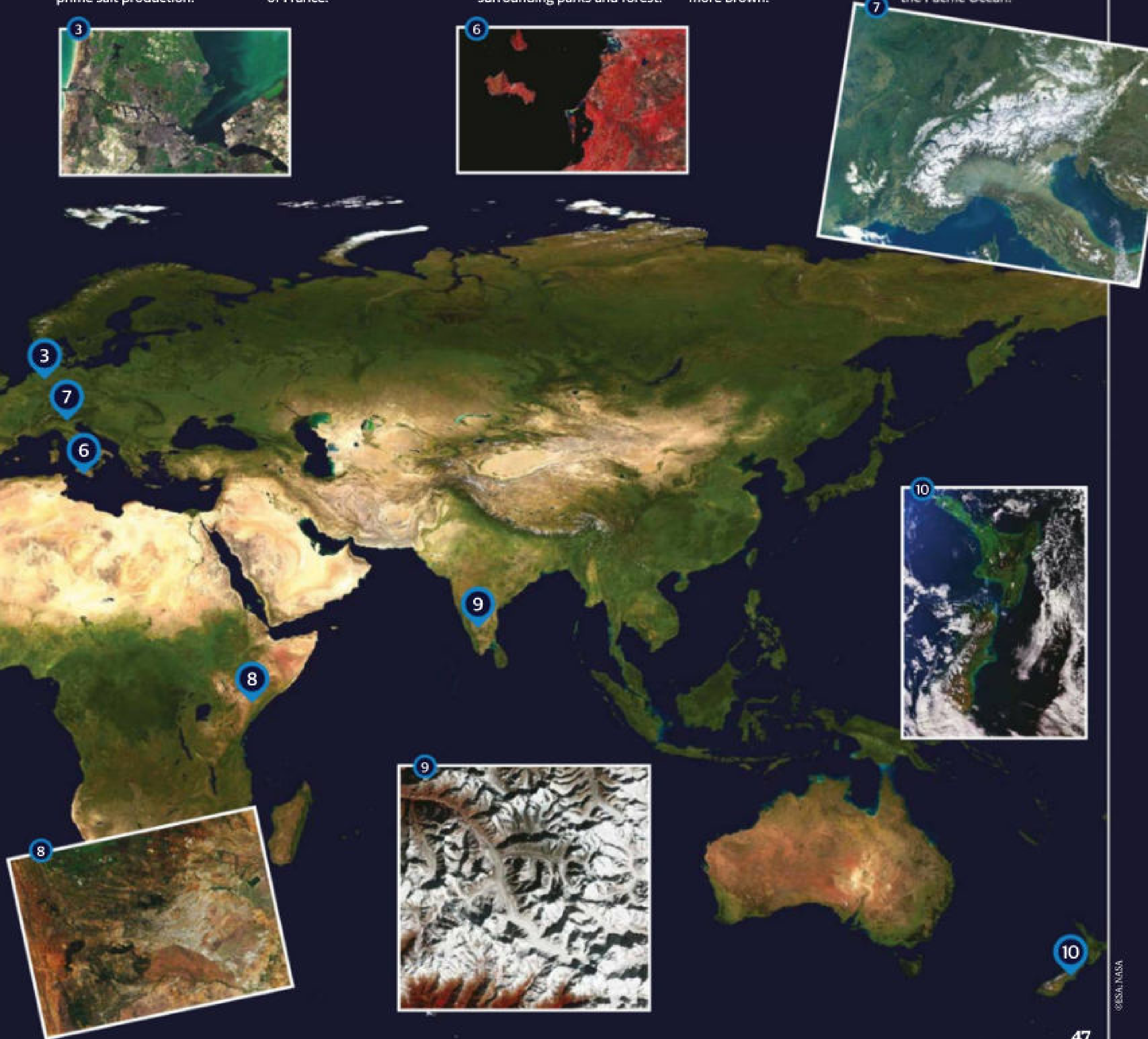
Nairobi is one of the fastest-growing cities in the world. The population has been growing by four per cent annually and is projected to have a population reaching five million by 2025. This makes it a better time than any to track and document the growth that is currently under steam in this eastern African city, especially with the environmental challenge of managing a growing city without damaging the surrounding parks and forest.

9 India

Grooves, elevations and a picture of white, red and brown is what makes up this Copernicus image of Gangotri – one of the largest glaciers in the Himalayas. This is also a main source of water for the famous Ganges River which runs through India. Unfortunately, it appears that Gangotri has been receding for the last 20 years, and the glacier has thinning. If it carries on, an image like this will become more and more brown.

10 New Zealand

New Zealand, the sovereign island county in the Pacific Ocean and the land of *The Lord of the Rings*, is a land rich with Polynesian culture and history. But from space it is rich with visually magnificent islands. This particular Copernicus image focuses on the Cook Strait that separates the north and the south islands, laminated on the east coast in the bright turquoise of sediment being carried into the Pacific Ocean.



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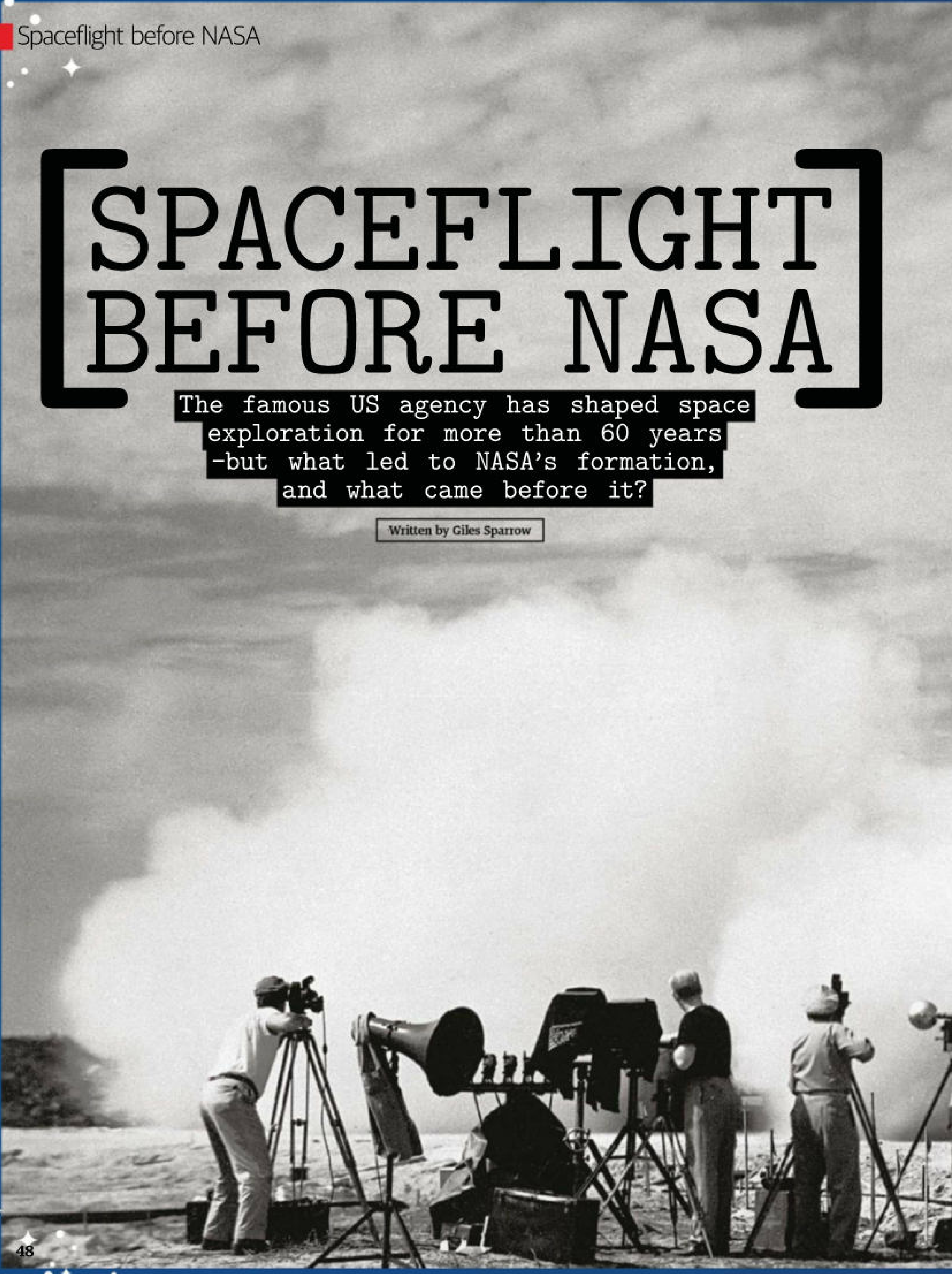
SPACEFLIGHT BEFORE NASA

The famous US agency has shaped space exploration for more than 60 years -but what led to NASA's formation, and what came before it?

Written by Giles Sparrow



Today NASA, the National Aeronautics and Space Administration, is a byword for the exploration of outer space, ranging from crewed flights to Earth orbit and groundbreaking scientific satellites and robotic exploration of distant worlds. Even when commercial companies or academic institutions take the publicity for new breakthroughs, it's often NASA funding that lies behind them.

The agency was established some 60 years ago, and after winning the Space Race with the Soviet Union in the 1960s, became the undisputed leader in world spaceflight - dwarfing the efforts of other regional agencies such as those of Europe, China and Russia itself. But the story of spaceflight before NASA is far from an all-American triumph - the agency was born in a time of national crisis and owed much of its success to advances made in earlier decades and other countries.

The story begins in the fraught political stalemate at the end of the Second World War. While a wartime alliance between democratic Western powers and the communist Soviet Union had been vital to defeating Nazi Germany, the last days of the war saw newly liberated Europe carved into two major spheres of influence from west and east. The prospect of a new long-term confrontation between former allies was clear, and both sides were keen to seize the spoils of war, including advanced German rocket technology.

While the early 20th century had seen rocket enthusiasts in several countries carrying out experiments and forming societies, the rocket's appeal had been greatest in Germany. Here, scientists and dreamers had been inspired by the writings of early spaceflight advocate Hermann Oberth and their depiction in early science-fiction movies. When the Nazi party seized power in the early 1930s, they too saw the rocket's potential as

Above: The 'Bumper' research rocket combined a V-2 lower stage with a small solid rocket upper stage

© NASA

How NASA was formed

The case for an overarching US space authority became clear after the Soviet Union's shock victory in the 1957 race to put a satellite in orbit

1 May 1957
Almost in orbit
The US Naval Research Laboratory fires a dummy satellite onto a suborbital flightpath using the first and third stages of its Vanguard rocket.

8 August 1957
Return from space
Wernher von Braun's Army rocket team use a Jupiter-C missile to fire a one-third-scale missile nose cone into space and study its condition after returning to Earth.

4 October 1957
Red star in orbit
The Soviet Union successfully launches the 84 kilogram Sputnik 1 satellite, an orbiting radio beacon whose signals are heard around the world.

8 November 1957
Project Orbiter reprieved
Following the Soviet launch of Sputnik 2, von Braun's team at Huntsville are authorised to begin preparations for a satellite launch as a backup for the Vanguard programme.

6 December 1957
Disaster on the launchpad
The Naval Research Laboratory's Vanguard TV-3 rocket, intended to put the first US satellite into orbit, explodes just two seconds into its flight.

"Some German rocket engineers found it hard to resist the lure of funding and political support"

a weapon of war. Some German rocket engineers refused to join the military effort, but others found it hard to resist the lure of funding and political support. Most were more interested in spaceflight than warfare, but the engineering problems were the same - reaching space would require a rocket far bigger than anything built so far, and the same rocket would have the potential to deliver a deadly explosive payload across hundreds of miles.

But progress was slow, and by the time the V-2 rocket, masterminded by engineering genius Wernher von Braun, was ready for production, Germany had already been mired in the Second World War for several years. The first rockets to fall on London in September 1944 brought sudden and terrifying death from the skies, but came too late to affect the outcome of the war as a whole.

As Germany's defeat became inevitable, the various allied powers were keen to obtain information on the V-2 programme. Von Braun's research centre at Peenemünde lay in the path of the advancing Red Army, but when Soviet soldiers arrived, they found the site stripped and the majority of its staff gone. The German 'rocket team' later surrendered, as they had hoped, to the Americans, while US soldiers also captured the main V-2 factory - a subterranean complex known as Mittelwerk, where inmates of the nearby Mittelbau-Dora concentration camp laboured, and often died, in appalling conditions.

The US Army rapidly began a wholesale relocation of equipment, documents, rocket parts and German engineers to American soil. The recruitment of the V-2 scientists, known as Operation Paperclip, remains controversial to this day, but they would play a key role in the early US space programme and the eventual success of NASA.

The Soviets, meanwhile, were left to gather what fragments were left at Peenemünde and elsewhere, and to sweep up lower-level workers from the area around the V-2 sites. The US therefore had a clear post-war advantage in the race for new long-range missiles, with the potential to fly on ballistic trajectories above Earth's atmosphere - its shock defeat in the early days of the Space Race was due in part to the genius of Soviet 'chief designer' Sergei Korolev, but also to mismanagement and political disinterest at home.

After arriving in the US, von Braun's team were first tasked with reassembling and launching captured V-2 rockets at New Mexico's White Sands Proving Ground. Several earlier V-2 tests had already achieved altitudes of more than 100 kilometres (62 miles), making them the first artificial objects to reach outer space, but the White Sands launches saw the first steps in scientific space exploration. Here, engineers began to work on ways of reaching higher speeds and altitudes, launching scientific instruments on short suborbital 'hops' into space and returning data from orbit.

A landmark came in February 1949 with the launch of 'Bumper 5', which used a modified V-2 to carry a WAC Corporal 'sounding rocket' to a high altitude before releasing it. The Corporal's own engine then took it much higher, reaching an altitude of almost 400 kilometres (249 miles) and returning data about space temperatures and solar radiation via radio signals.

Staying in space, however, was another matter. Boosting a payload to the high speeds necessary to achieve a stable orbit was far beyond even a modified V-2, and although studies carried out around this time concluded that launching a satellite into orbit was technically feasible, they cast doubt on whether the benefits could ever outweigh

31 January 1958
The US reaches orbit
The launch of the Explorer 1 satellite on von Braun's Juno launch vehicle puts America back in the Space Race – but with a lot of catching up to do.

7 February 1958
Ending the rivalries
President Eisenhower orders all US federal space projects to be brought under the control of ARPA, part of the Department of Defense.

5 March 1958
The advisors report
Eisenhower receives a formal recommendation from his scientific advisors to establish a new civilian agency controlling all non-military aerospace projects.

2 April 1958
The case for space
Eisenhower sets out the case for US engagement in space exploration and proposes the formation of NASA to Congress and the American public.

29 July 1958
NASA is born
Following approval of the National Aeronautics and Space Act in both houses of Congress, President Eisenhower signs the act into law.

1958 FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC 1959

Above: The German 'rocket team' were initially housed at Fort Bliss in Texas

Left: In comparison with US rockets of the time, the Soviet R-7 was far larger and more powerful

Far left: Despite its simple exterior and small size, Sputnik 1 carried a variety of experiments inside

Key figures

These were some of the major players in the early Space Race

Wernher von Braun
The German engineering genius behind the V-2 ballistic missile – after emigrating he worked on US Army rocket projects while advocating for a large-scale space programme.

Sergei Korolev
As head of the Soviet Union's OKB-1 design bureau he oversaw rocket and satellite development, including the R-7 launch vehicle, the Sputnik satellites and Vostok.

Milton Rosen
Head of the Naval Research Laboratory's Vanguard program, which after initial failures successfully launched three of America's first satellites in 1958 to 1959.

James R. Killian
President of the Massachusetts Institute of Technology and chief science advisor to President Eisenhower, Killian headed the committee that recommended NASA's formation.

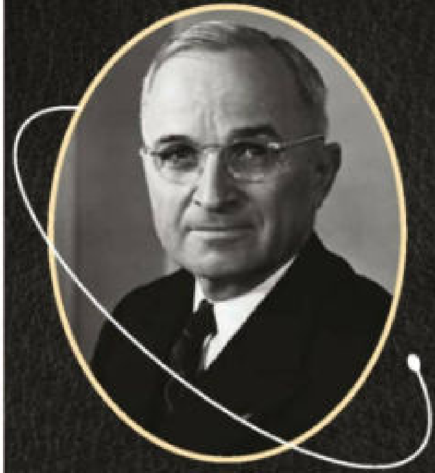
John B. Medaris
In charge of von Braun's rocket team at Huntsville, he made crucial decisions that permitted a rapid reinstatement of Project Orbiter and the launch of the US' first satellite.

T. Keith Glennan
Appointed by Eisenhower to head the newly formed NASA in 1958, he oversaw the agency's absorption of scattered space projects from across the military and civilian sectors and helped fashion NASA's long-term goals.

Hugh L. Dryden
The first NASA deputy administrator. He oversaw the development of high-altitude rocket planes and early moves towards US-Soviet cooperation in space research.

© NASA; [illegible] museum; National Air and Space museum; Alfred Eisenstaedt / Getty

The presidents that paved the way for space exploration



Harry S. Truman

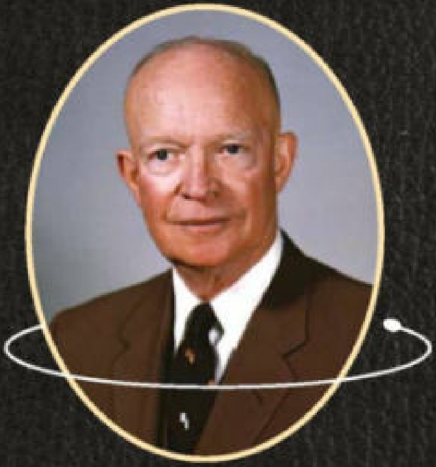
1945 to 1953

Oversaw Operation Paperclip, which imported German rocket scientists to the United States.

Initiated the first US attempts to build an intercontinental ballistic missile, but cancelled them as early as 1947 in favour of 'cruise' missiles that remain in Earth's atmosphere throughout their flight.

Several studies of the potential for satellite launches occurred in his administration, but none led to action.

Generally dismissive of even limited space exploration, describing the idea as "hooey".



Dwight D. Eisenhower

1953 to 1961

Advocated the civilian use of space and fought against its militarisation.

Backed the Naval Research Laboratory's Vanguard satellite launcher over the Army's 'Project Orbiter'.

Announced plans to launch a satellite during the IGY of 1957 to 1958.

Led the US response following the unexpected launch of Sputnik 1.

Approved the resumption of Project Orbiter, leading to the successful launch of Explorer 1.

Oversaw the formation of NASA, but in retirement came to doubt the value of manned spaceflight.

John F. Kennedy

1961 to 1963

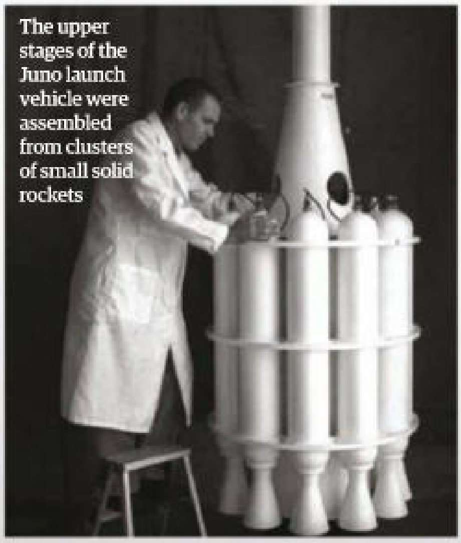
Exploited the supposed 'missile gap' with Russia in order to win the presidency.

Initially argued for international cooperation in space, only to have the offer rejected by Soviet Premier Khrushchev.

Responded to the Soviet launch of Yuri Gagarin, becoming determined that the US should win the Space Race for reasons of both security and prestige.

Oversaw the Mercury program that put the first US astronauts in orbit.

Committed the US to a manned lunar landing in the 1960s in a May 1961 speech to Congress.



The upper stages of the Juno launch vehicle were assembled from clusters of small solid rockets

the costs. President Harry S. Truman was famously dismissive of the concept of space travel - as late as 1956 he dismissed the concept as "hooey!" - and so rocket research efforts remained focused purely on missiles.

But at just this point, internal rivalries would deal a significant blow to US missile dominance. The Army, Navy and US Air Force (USAF) were each jostling to attract attention and funding to their own missile projects, and the end result was a fudge. The USAF was assigned to build a long-range intercontinental missile called Atlas, and the Army to concentrate on a shorter-range missile, while the Navy would develop a research rocket called Viking.

As Army employees, von Braun and his team were left to look on as the USAF absorbed most of rocket funding, while dawdling over development of Atlas - a vehicle capable of achieving their dreams of spaceflight. Their own 'Redstone' project, named after the Army arsenal in Huntsville, Alabama, where they were now based, presented relatively few new challenges, and was ready for flight by 1953.

So, in 1951, the sidelined advocates of spaceflight began a concerted PR offensive. Willy Ley, a well-known science writer who had fled Germany for the US before the war, organised a symposium on space travel in New York. This led to a series of wildly popular articles in *Collier's* magazine, outlining von Braun's vision for the colonisation of the Solar System. Walt Disney soon adapted the articles into a three-part television series, and astronaut suits began to outsell cowboy outfits as America went space-crazy.

The political winds were shifting, too. 1952 saw the announcement of a forthcoming International Geophysical Year (IGY) in 1957 to 1958 - an opportunity for scientific cooperation across the Cold War barriers, and an ideal time, many argued, to launch the first satellites. It also saw the election

© NASA; Bettmann / Getty

of Dwight D. Eisenhower, a new president who was far more open to the potential of space travel.

In mid-1954, von Braun was asked to join a top-level conference discussing possible satellite launch options. His solution was 'Project Orbiter', a modified Redstone missile topped with smaller solid-fuel rockets that would fire in clusters to act as two upper stages. Von Braun and his colleagues approached respected scientist James Van Allen to design the instruments for the satellite.

But when the US revealed its plans for a satellite launch during the IGY in December 1955, Project Orbiter was no longer in the frame. Rival scientists had launched a concerted attack, sniping at von Braun's design as awkward and risky, and arguing that taint of the V-2 and use of a military missile would diminish what should be an all-American triumph. Eisenhower, who had his own concerns about the potential militarisation of space, was persuaded to abandon Project Orbiter in favour of the Navy's Viking-based Project Vanguard. Meanwhile, the Soviet Union announced plans of their own to launch a satellite during the IGY, though few in the west took them seriously.

Von Braun's consolation prize was a contract to carry out limited sub-orbital space launches using the lower stages of Project Orbiter to investigate the effects of atmospheric re-entry. It was this project, known as Jupiter-C, that successfully returned the first object from space, a modified missile nose cone, in August 1957.

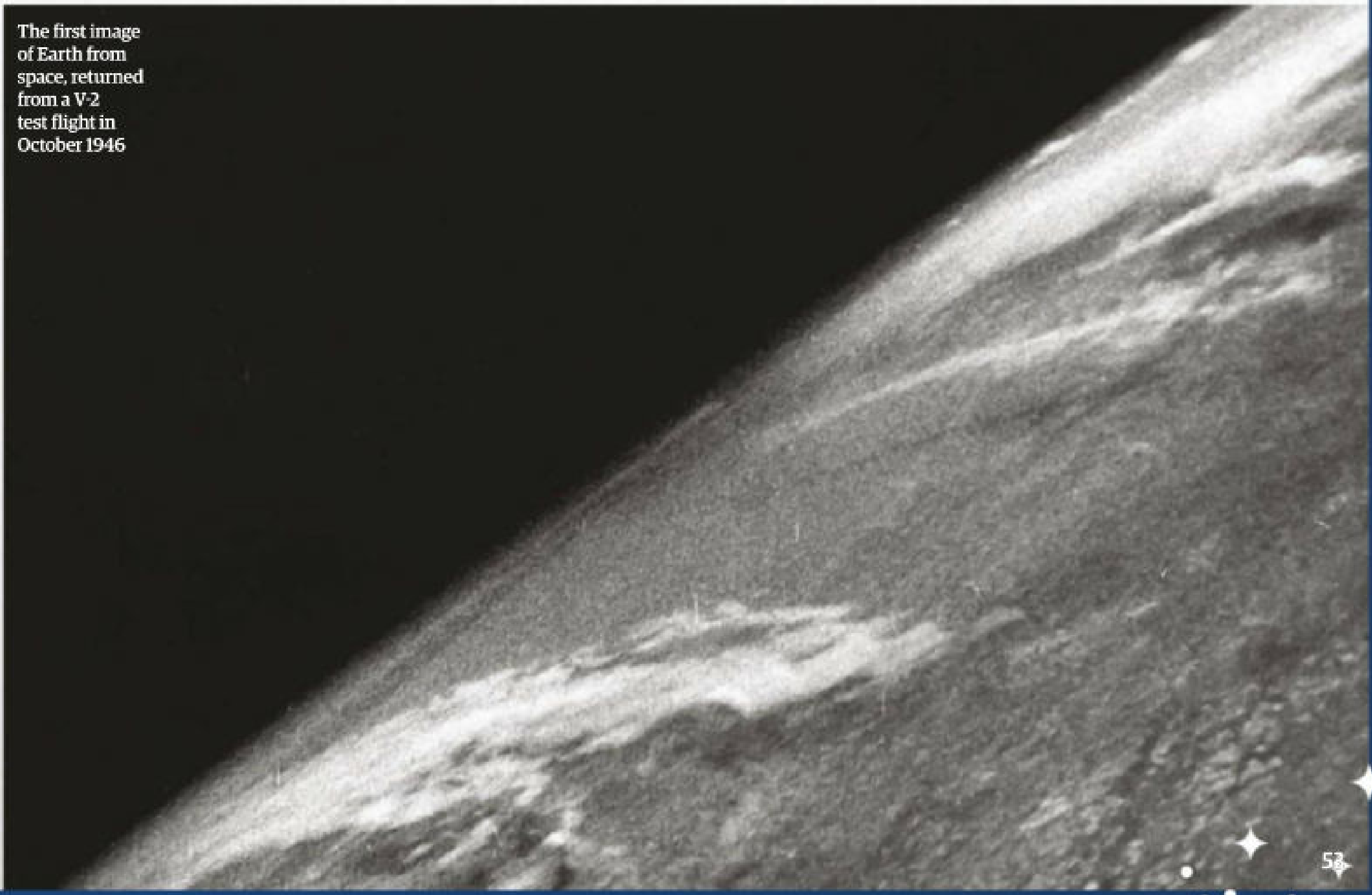
In the following months, the long prelude to the Space Race neared its endgame. While the Navy rushed to test the stages of its Vanguard rocket, the Soviet Union was secretly preparing a spaceshot of its own. From a weak starting position, Sergei Korolev and his engineers had accomplished a remarkable feat in building the R-7 missile – a monster rocket whose first stage consisted of four boosters, each larger than a V-2, clustered around a central core. An upper rocket stage gave the R-7 the capacity to put a satellite in orbit – one much larger than the grapefruit-sized objects being prepared for launch by Vanguard.

The Soviets played their hand with immaculate timing on 4 October, just as an IGY conference was meeting in New York. The launch of Sputnik 1 sent shockwaves around the world, and the media rushed to print stories about just what the new artificial moon could mean for the balance of global power.

As stunned Americans looked to their government for a response, Eisenhower coolly congratulated the Soviets on their launch of a 'small ball' into space, and indicated that a Vanguard satellite launch would go ahead as planned in early December. This was somewhat deceptive as no definite launch date had yet been set, and the routine response concealed surprise behind the scenes.

One person who remained calm, however, was Wernher von Braun. Questioned by the secretary of

Right: President Eisenhower (centre) with NASA deputy administrator Dryden (left) and administrator Glennan (right) at their swearing-in ceremony



The first image of Earth from space, returned from a V-2 test flight in October 1946

Left: The Project Orbiter committee that met to discuss US satellite launch options in 1955 - note von Braun in the foreground

Below left: The Vanguard TV-3 launch explodes above the launch pad at Cape Canaveral

Right: William H. Pickering of California's Jet Propulsion Laboratory, James Van Allen and Wernher von Braun hold up a model of Explorer 1 at a press conference after the successful launch

> "The successful launch of Explorer 1 restored some honour to the US space program"

defense, he insisted that a restarted Project Orbiter could launch a satellite in 90 days. But it was not until November - after the Soviets had launched the larger and far more sophisticated Sputnik 2, carrying space dog Laika - that Eisenhower overcame his qualms and gave the go-ahead.

The wisdom of this 'insurance policy' became clear in early December when the first fully assembled Vanguard rocket blew up moments after launch. The press and other media, who had gathered in huge numbers expecting to see the first US satellite launch, nicknamed it 'Flopnik'.

Despite the groundwork laid, von Braun's team still had to race to meet their launch target of late-January 1958. Cosmetic changes to the rocket, including renaming it 'Juno', helped distance it from its military origins, but a satellite had to be built from scratch. The eventual design, dubbed 'Explorer 1', was a modified solid rocket casing with the top half allocated to Van Allen's scientific instruments - the bottom remained a functional rocket, turning Juno into a four-stage launch vehicle.

The successful launch of Explorer 1 on 31 January 1958 restored some honour to the US space program, but America was still clearly lagging behind Soviet achievements. As the Space Race began in earnest, ideas flew around for everything from spy satellites to manned spacecraft. The USAF, eager to make up for the Army and Navy's dominance in space so far, developed several options for a 'Man in Space Soonest' Project. These included rocket-powered 'X-planes', experimental aircraft designed in conjunction with NACA, the National Advisory Council on Aeronautics, and a manned capsule launched by a converted Atlas missile.

Anxious to avoid further damaging rivalry, President Eisenhower ordered that all space projects should be temporarily brought under the control of the Defense Department's Advanced Research Projects Agency (ARPA). At the same time he asked a committee of scientific advisors to draw up long-term plans for a national space science programme.

A few weeks later the committee delivered its recommendation for a new civilian space agency that would succeed NACA and control all US space projects, except for those with explicitly military applications. On 2 April, Eisenhower gave the idea his formal backing, calling for the establishment of a 'National Aeronautical and Space Agency' with wide-ranging powers and responsibilities. With legislation passed by both houses of Congress, NASA came into being on 29 July 1958.

In the years that followed the new agency would absorb many of the pre-existing US space efforts. Von Braun's team at Huntsville, for example, would form the core of the new Marshall Space Flight Center, while research for 'Man in Space Soonest' would prove useful in designing the Mercury capsule that eventually carried the first Americans into space. NASA's creation may have ended a fascinating period in space history, but it brought much-needed focus to the US space effort - and while there would be plenty of other setbacks along the way, without NASA the race to put astronauts on the Moon and seal victory in the Space Race might have played out very differently.

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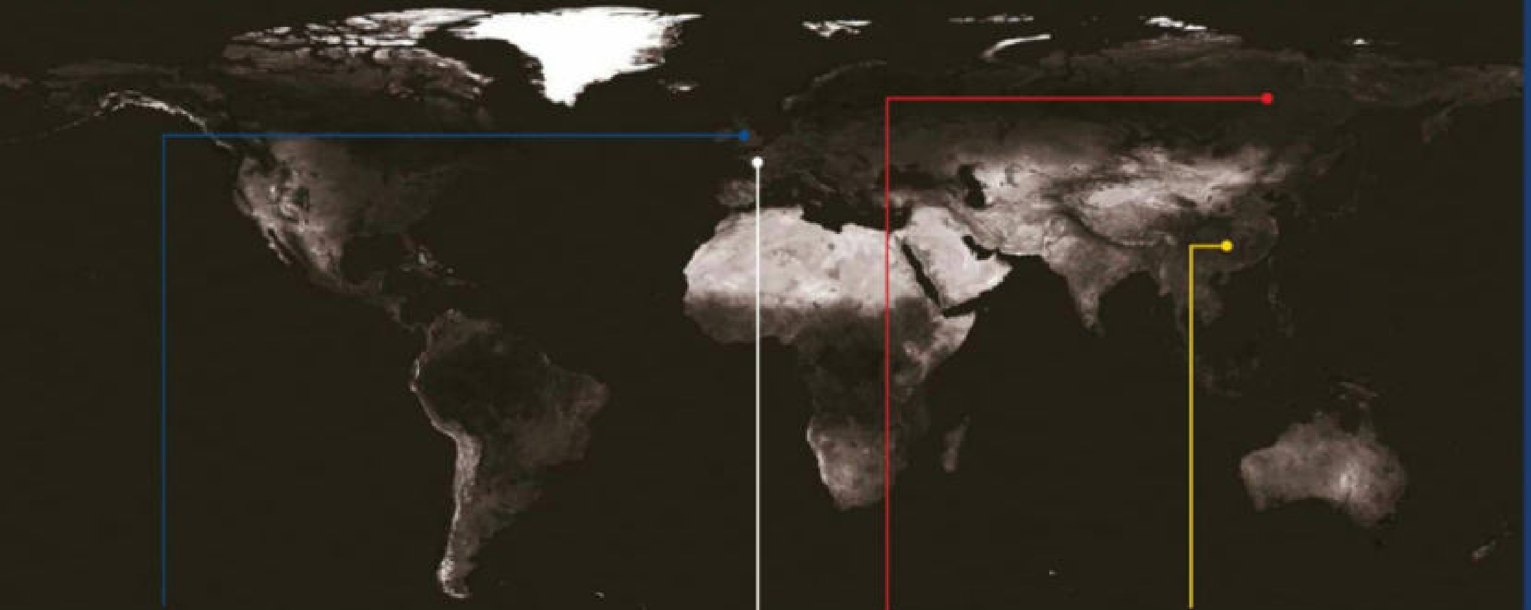
The rest of the world

While America's space programme was to have the greatest influence on the future, the US was not the only country racing for space in the years after the Second World War



United Kingdom

1945 to 1971

Britain's 'Operation Backfire' tested captured V-2 rockets shortly after World War II, and the UK developed its own ballistic missile and launcher development programme before it was cancelled due to budget cuts in the early 1970s.

France

1945 to present

France pursued its own missile programme after World War II. A space agency was established in 1961 and the first French satellite, Asterix, was launched in 1965. From the 1970s, France became a leading member of the European Space Agency.

Soviet Union

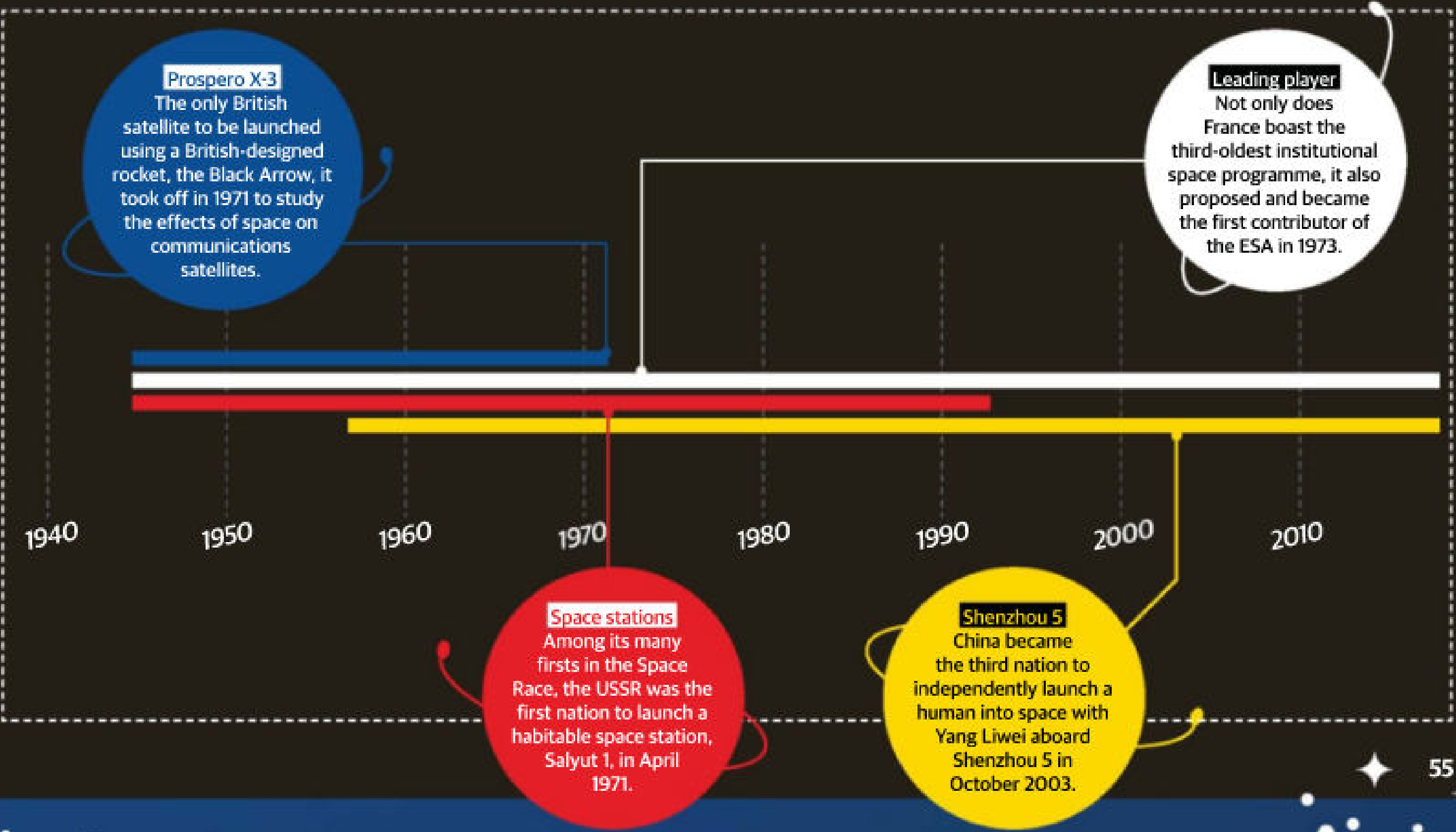
1945 to 1991

Political will and engineering genius gave the Soviets an early lead in the Space Race, which faltered after Korolev's death in 1966. Nevertheless, the Soviet Union continued as a major power until its dissolution, and Russia inherited much of its space knowhow.

China

1957 to present

China sought to develop its own space programme following the launch of Sputnik 1 in 1957. Initially the Chinese benefited from technology shared by the Soviets, but after relations cooled, progress slowed.



Prospero X-3

The only British satellite to be launched using a British-designed rocket, the Black Arrow, it took off in 1971 to study the effects of space on communications satellites.

Leading player

Not only does France boast the third-oldest institutional space programme, it also proposed and became the first contributor of the ESA in 1973.

Space stations

Among its many firsts in the Space Race, the USSR was the first nation to launch a habitable space station, Salyut 1, in April 1971.

Shenzhou 5

China became the third nation to independently launch a human into space with Yang Liwei aboard Shenzhou 5 in October 2003.

CHINA PLANS TO BUILD A MOON BASE

The Chinese space agency is looking to build on our satellite in the next ten years

Reported by Rafi Letzter

China plans to build a scientific research station on the Moon in "about ten years", according to the state news agency Xinhua.

The China National Space Administration (CSNA) intends to build the research station in the region of the Moon's south pole, Zhang Kejian, head of CSNA, said in a public statement, Xinhua reported. That's a bit of a departure from the six successful NASA Apollo Moon landings, which took place closer to the Moon's equator between 1969 and 1972.

Details of China's long-term lunar plans are still sketchy, but CSNA has made significant steps towards lunar exploration. Earlier this year the Chinese successfully landed the uncrewed Chang'e 4 on the far side of the Moon, and CSNA has also placed astronauts aboard two temporary space stations, Tiangong-1 and Tiangong-2. The space agency also plans to put a larger, more permanent station into orbit in the coming years.

The first parts of that permanent station will reach orbit aboard the country's new Long March 5B rocket in the first half of 2020, Agence France-Presse (AFP) reported; the mission will not be associated with the International Space Station (ISS). The ISS is reaching the end of its operational lifetime, plus the United States and China do not cooperate on spaceflight endeavours.

Kejian also announced that Chang'e 5, an uncrewed lunar lander originally scheduled for launch in 2017, will attempt to reach the Moon and return with samples in 2019, Xinhua reported.

China currently spends more on spaceflight than any country except the US, according to AFP. At the moment the US is unable to put humans in space without hitching a ride on a Russian rocket; plans to change that model by using for-profit rockets – such as those owned by SpaceX – have hit some snags. Still, American officials have also suggested that there are plans to return to the Moon and stay on the satellite for an extended period in the near future.

Above: Many space agencies and private companies want to return to the Moon

Right: China's Long March 5B rocket is the country's current launch vehicle

"The space agency also plans to put a larger, more permanent station into orbit in the coming years"

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NEW DISCOVERY!

THE PARTICLE THAT'S NOT A PARTICLE

First proposed in the 1970s, the LHC may have finally found evidence of the elusive odderon

Reported by James Romero

"There are very rare cases in the history of physics that a scientific and testable idea is neither proved nor disproved 33 years after its invention," wrote Basarab Nicolescu in a 2007 paper, describing over a quarter of a century of debate over the odderon. A virtual - or quasi - particle, Nicolescu believed it played a vital role in forming the matter of the universe by keeping atomic nuclei locked together.

However, having never been observed, did it really exist? Another decade on and Nicolescu may finally have closure on his proposed particle, following a recent experiment carried out at the Large Hadron Collider (LHC). These results suggest it is finally time to welcome a new virtual member to our particular family of fundamental components of cosmic stuff that have been observed inside the world's largest and most powerful particle accelerator. But what do we mean by a virtual particle?

> "The odderon is a compound of gluons as a proton is a compound of quarks and gluons"
>
> **Simone Giani**

The story starts in quantum field theory, a set of equations that give physical form to subatomic particles by describing them as excited states of a more fundamental underlying field. In this framework the interactions between ordinary, familiar particles - what we tend to think of as forces - are described as the exchange of virtual particles, which are similar to ordinary particles, except their excited states last only momentarily. Electromagnetic repulsion or attraction, for example, can be thought of as the exchange of virtual photons, where the virtual photon is the force carrier.

Why isn't the odderon a particle?

The odderon: a virtual particle

Quantum field theory describes virtual particles like the odderon as temporary excited states of an underlying field which are exchanged between the permanent excited states of the ordinary particles that make up atoms and matter.

The odderon was first proposed by Leszek Lukaszuk and Basarab Nicolescu in 1973 as a potential force carrier for the strong interaction - or nuclear - force. This is the attractive force between protons and neutrons which tends to overcome the electromagnetic repulsion of similarly charged protons in the atomic nucleus, holding it all together. Despite this vital role, some have tended to demote the odderon and its like to that of 'quasiparticles'.

Paul M. Sutter, an astrophysicist at Ohio State University, writing for **livescience.com** this year, described quasiparticles as "brief, effervescent patterns or ripples of energy that appear in the

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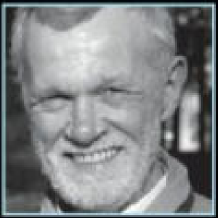
What does the odderon tell us about the universe?

From glueballs and future technology to shining a light on the Standard Model, particle physicists assess the impact of the detection

The odderon as a standalone particle

"The main implications are, both mathematically and empirically, that when a particle exists in its virtual state to mediate interactions, it should also exist as a standalone particle. For the case of the gluons under discussion, it is called 'glueball'."

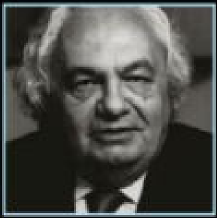
Simone Giani, CERN



Glueball detection

"There were many attempts to see the odderon as glueball in many processes differed of elastic scattering. However, until now nobody detected such a glueball."

Evgenij Martynov, National Academy of Sciences of Ukraine



Disproving naïve expectations

"A spectacular possible consequence of the odderon is the fact that the proton-proton total cross section could be bigger than the antiproton-proton total cross section at very high energies, contrary to naïve expectations."

Basarab Nicolescu, Centre National de la Recherche Scientifique

Shining a light on the Standard Model

"This doesn't break the Standard Model, but there are very opaque regions of the Standard Model, and this work shines a light on one of those opaque regions."

Timothy Raben, Michigan State University

Odderon tech

"When electrons were discovered, no one had a clue as to what they would eventually be important for. We're in a similar situation right now with QCD; we don't know what we'll do with this knowledge in the future, but it could be critical information for building in future technologies."

Jerome Luine, Northrop Grumman Next Basic Research

Confirming what we already knew

The experimental discovery of the odderon would not add much new information to our understanding of the universe. It has been known for quite a long time that the odderon firmly exists in QCD.

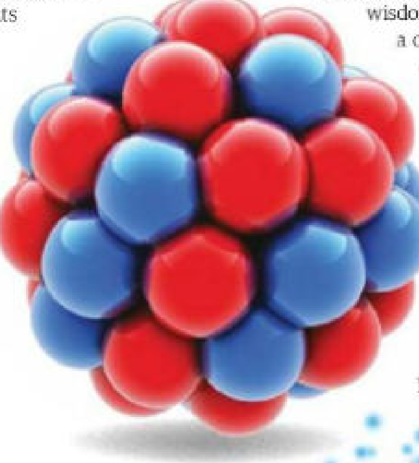
Valery Khoze, University of Durham

"Physicists take some shortcuts and pretend that these patterns are their own particles, so quasiparticles are treated like particles even though they aren't" **Paul M. Sutter**

midst of a high-energy particle collision. Since it takes a lot of legwork to fully describe that situation mathematically, physicists take some shortcuts and pretend that these patterns are their own particles. So, quasiparticles are treated like particles even though they definitely aren't."

Not everyone likes this term, nor the implications for the status of the particles given it. "I do not agree with the concept of the so-called quasiparticles," says CERN's Simone Giani. "The odderon is a compound of gluons as a proton is a compound of quarks and gluons; as an atom is a compound of protons, neutrons and electrons; as a molecule is a compound of atoms."

Whatever name you prefer, the work of Lukaszuk and Nicolescu suggested the odderon could appear fleetingly in specific, high-energy but non-destructive, low-angle collisions of protons and antiprotons. Such interactions produce complex sequences of events involving the exchange of energy between colliding components, and its conversion into matter in the form of new particles.



Timothy Raben, a post doctoral theoretical physicist at Michigan State University and colleague of Giani, described these mash-ups "like two big semi trucks that are transporting cars, the kind you see on the motorway. If those trucks crashed together, after the crash you'd still have the trucks, but the cars would now be outside, no longer aboard the trucks - and also new cars are produced as energy and transformed into matter."

However, before exploring ways to test their theory, Lukaszuk and Nicolescu first had to face the backlash. Back in the 1970s their odderon theory went against a lot of conventional wisdom of the time. "Once I started a conference on hadronic elastic scattering saying that proton-proton versus proton-antiproton strong interactions have always been assumed to be identical, and never observed experimentally to be identical," recalls Giani. "The old community is very much against it."

"Revolutionary, if not heretical" was the phrase Nicolescu used in a recent paper published in *Physics Letters B* with Evgenij Martynov to described how his propositions sat among the scientific consensus. However, it wasn't long before supporting evidence came to light. Seven years after its introduction to the world of particle physics, the odderon was rediscovered in a second set of equations. This time it was as an essential prediction of quantum chromodynamics (QCD), the theory that describes the strong interaction between quarks and gluons, the fundamental components that make up hadrons such as protons and neutrons.

QCD theory described the odderon as a compound of three, or a larger odd number, of gluons which are exchanged between protons interacting via the strong force. However, odderons are not the only one to facilitate this interaction. Compounds of an even number of gluons can do the same job, with such virtual particles instead named pomerons.

However, the QCD evidence was supportive rather than definitive, and the theory still very much had its critics. Back in 1990 at the annual Rencontres de Moriond conference of new ideas in physics, Nicolescu explained his continued belief in his theory by quoting 19th-century French scientist Claude Bernard: "When a fact arises which is in contradiction with a dominant theory, one has to accept the fact and to give up the theory, even if this theory is supported by famous names and it is generally accepted." In the same talk Nicolescu had some choice words for the criticism his theory had faced, which he said had sometimes taken the form of a religious language.

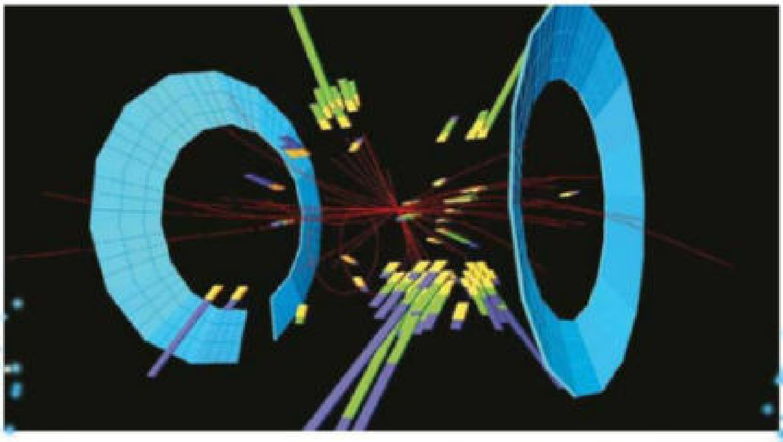
"One can ask ourselves if, in the light of recent QCD results, the heretical is becoming now sacred. In any case, I cannot agree with such a religious language," he declared. It was clear the only way to end the speculation was a direct observation of the odderon. However, in all previous experiments only 'pomeronic', even-numbered gluon compounds were detected being exchanged during collisions.

One option was to look for products of subsequent odderon bonding. The three-gluon virtual particle was thought to be able to fuse with other particles emitted from the smashed-up proton - such as a light-carrying photon - creating mesons, another family of subatomic particles composed of one quark and one antiquark. This could be detected with the particle accelerators of the time. However, such processes are dominated by pomerons and pomeron-photon exchanges, making the observation of a three-gluon state difficult.

Another approach proposed comparing the cross sections of particle-antiparticle collisions with that of proton-proton collisions to look for predicted differences in the profiles. All that was required were machines capable of repeatedly smashing protons and protons and protons and antiprotons together at the requisite energies.

However, by the mid-2000s there was a lack of facilities available to perform such experiments. The Intersecting Storage Rings (ISR), a particle accelerator at CERN and the world's first hadron collider, had offered the first strong hint for the existence of the odderon, but it closed shortly after in the mid-1980s. "This is the main reason of the non-observation till now of the odderon," wrote Nicolescu in 2007, shortly after the death of Lukaszuk. However, his lament at the limitations of experimental set-ups, was accompanied with hope for the future: "Another crucial and spectacular test of the possibility at high energies would be offered by the LHC collider. It would be a pity not to continue the comparison of p·ap and p·p scattering which is, of course, of great importance to an understanding of strong interaction dynamics."

Though the first experiments were run at CERN's Large Hadron Collider (LHC) in 2008, it would take until 2015 for it to be operating at sufficiently high energy to look for the odderon. In the meantime the DZero experiment at the Fermi National Accelerator Laboratory in the US was providing comparative data with precise studies of the interactions of protons and antiprotons at the highest available energies offered by its Tevatron collider. If the LHC could collect proton-proton



Right: The typical outcome of a collision of a proton and an antiproton

Below: The strong nuclear force carried by gluons and odderons stores incredible amounts of energy

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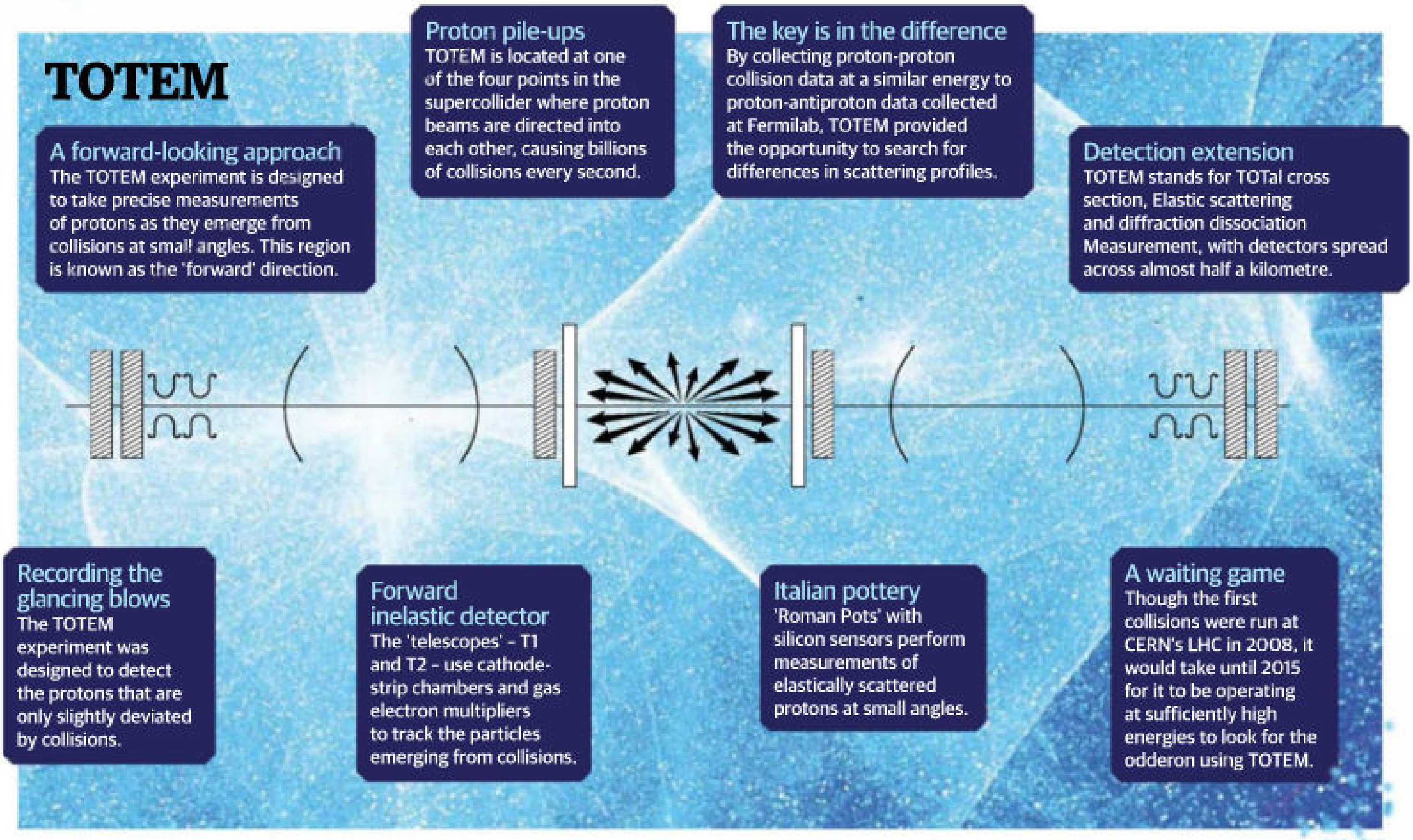


TOTEM

A forward-looking approach

The TOTEM experiment is designed to take precise measurements of protons as they emerge from collisions at small angles. This region is known as the 'forward' direction.

Proton pile-ups

TOTEM is located at one of the four points in the supercollider where proton beams are directed into each other, causing billions of collisions every second.

The key is in the difference

By collecting proton-proton collision data at a similar energy to proton-antiproton data collected at Fermilab, TOTEM provided the opportunity to search for differences in scattering profiles.

Detection extension

TOTEM stands for TOTal cross section, Elastic scattering and diffraction dissociation Measurement, with detectors spread across almost half a kilometre.

Recording the glancing blows

The TOTEM experiment was designed to detect the protons that are only slightly deviated by collisions.

Forward inelastic detector

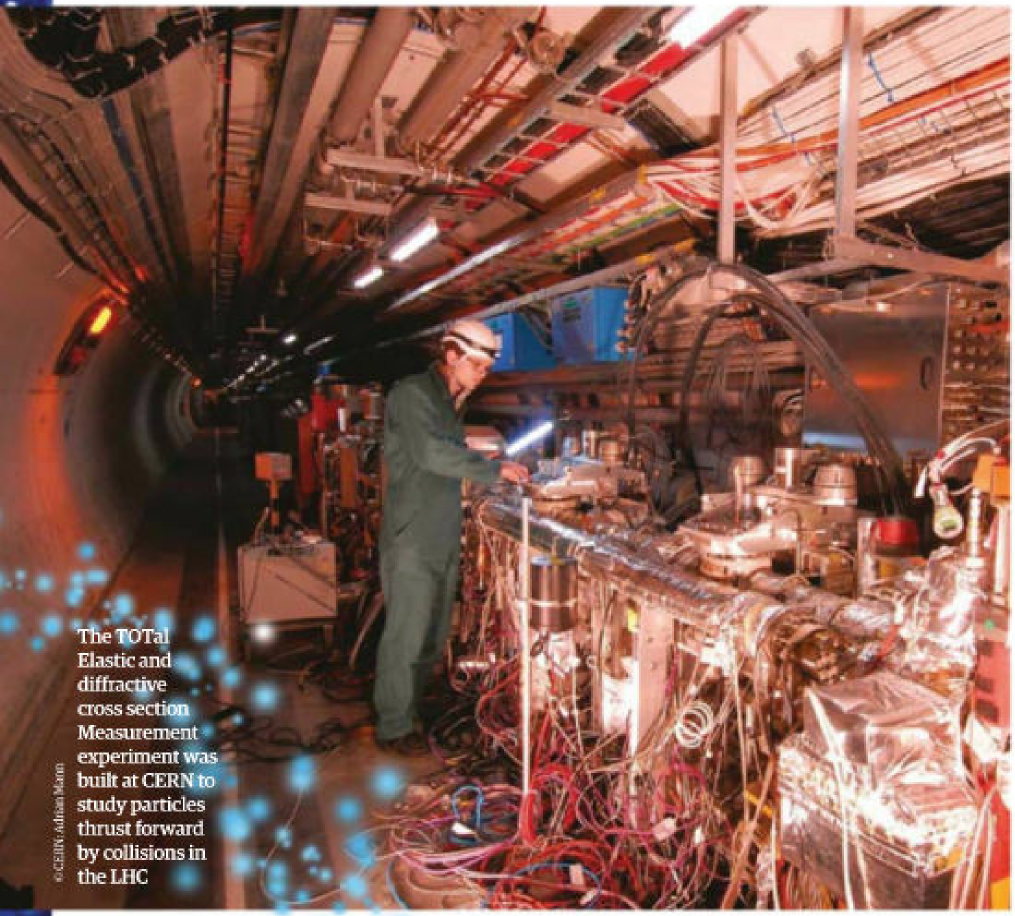
The 'telescopes' – T1 and T2 – use cathode-strip chambers and gas electron multipliers to track the particles emerging from collisions.

Italian pottery

'Roman Pots' with silicon sensors perform measurements of elastically scattered protons at small angles.

A waiting game

Though the first collisions were run at CERN's LHC in 2008, it would take until 2015 for it to be operating at sufficiently high energies to look for the odderon using TOTEM.



The TOTal Elastic and diffractive cross section Measurement experiment was built at CERN to study particles thrust forward by collisions in the LHC

©CERN; Adrian Mann

collision data performed at similar energies then direct comparison would allow the team to identify any differential elastic scattering cross sections caused dominantly by an odderon contribution.

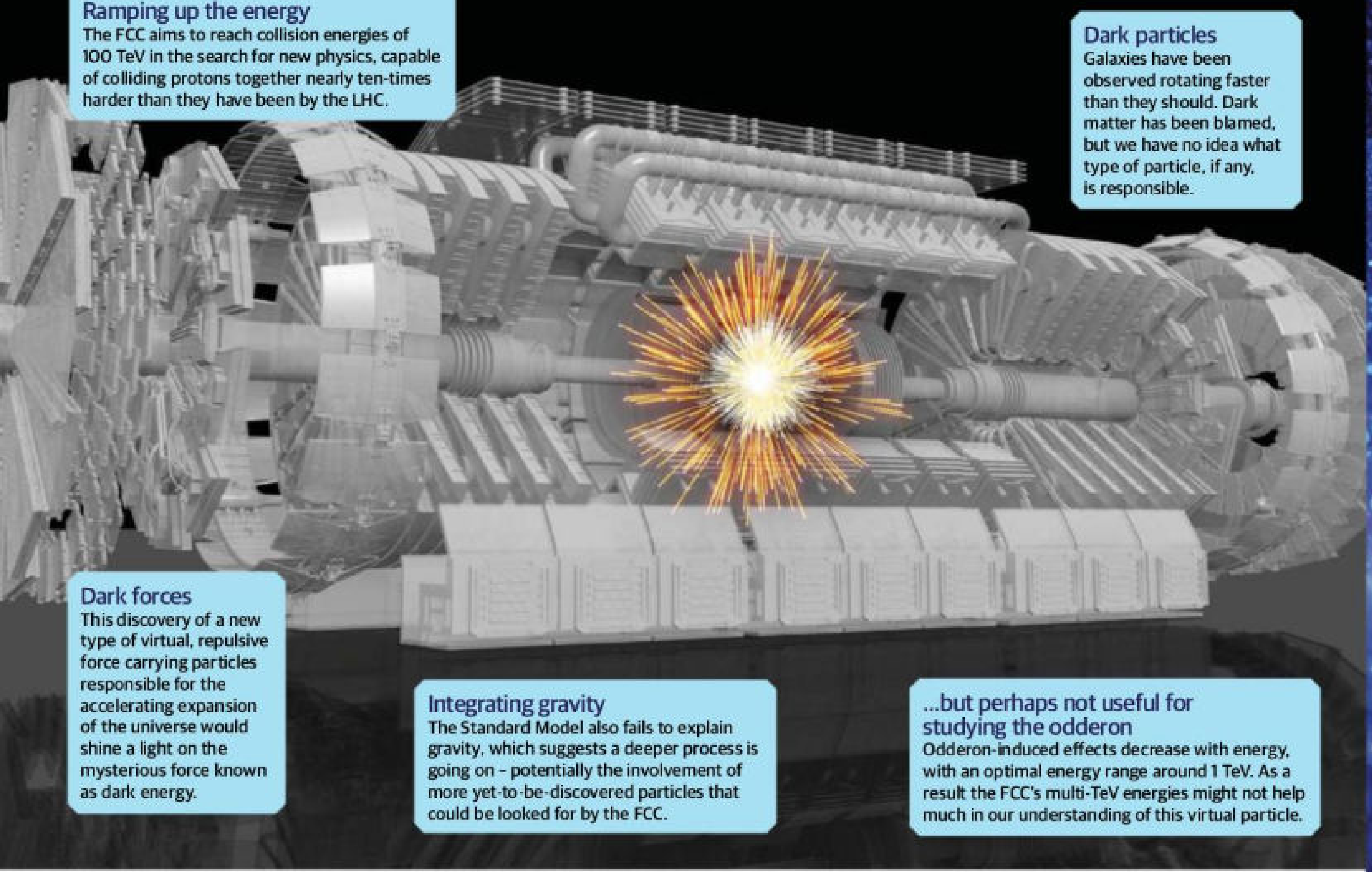
The LHC instrument for the job was the TOTal Elastic and diffraction dissociation Measurement experiment (TOTEM). TOTEM has detectors spread across almost half a kilometre from one of the four points in the supercollider where proton beams are directed into each other, causing billions of collisions every second. Rather than observing the obliteration of full-on collisions, the TOTEM experiment was designed to detect protons that are only slightly deviated by collisions. "They represent about 25 per cent probability of what may happen in an LHC collision between protons. In the remaining 75 per cent they break," says Giani.

Analysis of these interactions at TOTEM was compared with the highest energy results from the DZero in a paper published in December 2018. Almost half a century after the odderon was first predicted, and despite an 800 GeV gap in the energies of collisions, Giani and his colleagues were able to announce with an "extremely high degree of confidence and significance" that they had their virtual particle. "The difference is characterised by the oscillation into a dip and then a local max, which are present in the p-p differential cross section [recorded at TOTEM] and not in the pp-bar differential cross section [recorded at DZero]," says Giani.

However, that 800 GeV difference still represents a small leap of faith, so Giani and his colleagues will soon publish a joint paper with the DZero team

Completing our understanding: The Future Circular Collider

The particle smasher has been proposed as a higher performance particle collider to extend LHC research



Ramping up the energy
The FCC aims to reach collision energies of 100 TeV in the search for new physics, capable of colliding protons together nearly ten-times harder than they have been by the LHC.

Beyond the Standard Model
When the LHC was first proposed it was hoped it could discover particles beyond the Standard Model. It has failed, but perhaps the higher energies of the FCC might provide the key.

Dark particles
Galaxies have been observed rotating faster than they should. Dark matter has been blamed, but we have no idea what type of particle, if any, is responsible.

Dark forces
This discovery of a new type of virtual, repulsive force carrying particles responsible for the accelerating expansion of the universe would shine a light on the mysterious force known as dark energy.

Integrating gravity
The Standard Model also fails to explain gravity, which suggests a deeper process is going on – potentially the involvement of more yet-to-be-discovered particles that could be looked for by the FCC.

…but perhaps not useful for studying the odderon
Odderon-induced effects decrease with energy, with an optimal energy range around 1 TeV. As a result the FCC's multi-TeV energies might not help much in our understanding of this virtual particle.

> "This doesn't break the Standard Model, but there are very opaque regions of the Standard Model, and this shines a light on one of those opaque regions" **Timothy Raben**

to confirm the results after extrapolating them to a common energy.

"The DZero data by itself cannot establish evidence for the odderon. But when one takes both DZero data at 1.96 TeV for antiproton-proton and TOTEM data for proton-proton at the close value of 2.76 TeV, one finds a strong evidence for the odderon," says Nicolescu.

Further modelling since published claims to confirm that for any model to be consistent with TOTEM's data, a three-gluon-state exchange was essential. Nicolescu himself, writing with Martynov in *Physics Letters B* in March 2018, confirmed their own analysis of the results showed that the new TOTEM datum can be considered as the first experimental discovery of the odderon. "The odderon must be present in order to explain the new TOTEM datum," they wrote.

So what does the odderon confirmation mean for particle physics and our wider understanding of the cosmos? "The main implications are, both mathematically and empirically, that when a particle exists in its virtual state to mediate interactions, it should also exist as a standalone particle," says Giani. "This doesn't break the Standard Model, but there are very opaque regions of the Standard Model, and this work shines a light on one of those opaque regions," Raben said in the press release that accompanied their 2018 paper.

Jerome Luine, principal scientist at Northrop Grumman Next Basic Research, told *Now* magazine – the company's research title – that it is unlikely we will know all the consequences of this observation right away. "When electrons were discovered, no one had a clue as to what they would eventually be important for. Now, of course, it's the basis for all our electronics. We're in a similar situation right now with QCD; we don't know what we'll do with this knowledge in the future, but it could be critical information for building in future technologies."

However, perhaps simply ending nearly half a century of speculation is reason to celebrate in its own right as we welcome a new member to our (virtual) particle family.

BLACK HOLES WHAT IS STILL UNKNOWN?

The Event Horizon Telescope released the first-ever image of the behemoth at the centre of Messier 87… but what questions still linger?

On 10 April 2019, the world was introduced to the very first picture of a black hole. It was taken using a worldwide collection of radio telescopes, forming what is known as the Event Horizon Telescope (EHT), which focused its attention on the centre of a galaxy 55 million light years away, Messier 87. This is a feat comparable to reading a newspaper that's in New York while sitting down in a street in Paris – a job only made possible by combining the power of eight telescopes from around the world. The final image of the black hole has allowed astronomers the opportunity to combine computer models with direct observations, thus confirming or denying many pre-existing theories. But this doesn't mean that all the questions have been answered, including some pretty big ones.

For starters, how do black holes produce their enormous jets of hot, fast matter? Well, all supermassive black holes have the ability to chew up nearby matter, absorb most of it past their event horizons and spit the remainder out into space at near-light speed in blazing towers astrophysicists call 'relativistic jets'. M87 is renowned for its enormous jets, and while the EHT has imaged an impressively small object, the jets take up a much larger area. In order to learn more, linking up more EHT observations is critical in understanding these features further.

Another mystery is how general relativity and quantum mechanics fit together. Quantum gravity is the great unknown in physics. For about a century, physicists have worked using two different sets of rules: general relativity, which covers very big things like gravity, and quantum mechanics, which covers very small things. The problem is that these two rulebooks directly contradict one another. Quantum mechanics can't explain gravity, and relativity can't explain quantum behaviour. Physicists hope to link the two together in a grand unified theory, likely involving some sort of quantum gravity. The black hole image was as predicted from a general relativity perspective, so it offered no new physics that might close the gap. Still, it's not crazy that people hope for answers from this sort of observation, because the edge of a black hole's shadow brings relativistic forces into tiny, quantum-size spaces.

Another question remains whether Stephen Hawking's theories are as correct as Einstein's. The physicist Stephen Hawking's greatest early career contribution to physics was the idea of 'Hawking radiation' – that black holes aren't actually black, but emit small amounts of radiation over time. The result was hugely important because it showed that once a black hole stops growing, it will start to very slowly shrink from the energy loss. But the EHT didn't confirm or deny this theory – not that anyone expected it to. Giant black holes like the one in M87 emit only minimal amounts of Hawking radiation compared to their overall size. While our most advanced instruments can now detect the bright light of event horizons, there's little chance that they will ever tease out the ultra-dim glow of a supermassive black hole's surface.

Below: Artist impression of M87's black hole shows relativistic jets launched perpendicular to the object's accretion disc

> “Giant black holes like the one in M87 emit only minimal amounts of Hawking radiation compared to their overall size”

© ESO, EHT Collaboration

ULTIMA THULE A FUTURE COMET?

The Kuiper Belt Object has had a quiet past, but with a radical change it could transform into a dirty space snowball

Reported by Lee Cavendish

NASA's New Horizons brought the darkened realm beyond Neptune to light. This region, also known as the Kuiper Belt, is full of objects left over from the formation of the Solar System. These frozen time capsules could well be hiding the answers to what happened in its genesis. After NASA's incredible flyby of Pluto, the New Horizons spacecraft made history once again when it sought out Kuiper Belt Object (KBO) (486958) 2014 MU69, nicknamed Ultima Thule. The flyby of Ultima Thule on 1 January 2019 had astronomers marvelling at its appearance, and they have been attempting to apply any new discoveries to any gaps in our knowledge - in this case, comets.

When Ultima Thule came into shape, the first thought that came to mind for some was its stunning resemblance to Comet 67P/Churyumov-Gerasimenko. This particular comet was the subject of an intense examination period when it was paid a visit by the European Space Agency's Rosetta spacecraft, along with the Philae lander, on 6 August 2014. This mission caught the comet at its closest point to the Sun, known as a perihelion, 186 million kilometres (116 million miles) from the Sun.

This 6.5-year orbit takes it outwards to the orbit of Jupiter, but when comets get close to perihelion they undergo maximum sublimation as material is stripped away by the Sun's heating effect. A comet's nucleus contains the constituent material that accreted in the early Solar System, but sublimation occurs at a closer distance to the Sun. This creates a tiny atmosphere known as a coma, the solar winds sweeping away material to form an ion tail, while normally larger pieces of material form a separate dust tail which travels at a 45 degree angle between the comet's path and the ion tail.

The Rosetta mission brought back a host of data that has led to some remarkable discoveries, including that a surprising amount of water vapour is released from the surface, along with measurements of deuterium - hydrogen with one proton and one neutron - nitrogen, oxygen and argon. Due to this, astronomers deduced this comet is much more ancient than first thought. Overall analysis has estimated that Comet 67P formed from cold components of the interstellar cloud of gas and dust that populated the area around the Sun 4.6 billion years ago. This is the same sort of time period astronomers predict that Ultima Thule was conceived.

My other vehicle explored Pluto

Alas, saying Ultima Thule and Comet 67P are two of the same is completely wrong. "Comets come from a part of the Kuiper Belt millions of miles away from where Ultima Thule is, which is called the 'scattered disc'. Ultima Thule is from the cold 'classical region' [in the Kuiper Belt] which is completely different," Dr Alan Stern, principal investigator of the New Horizons mission, tells **All About Space**. "It is as different as North America versus Europe.

"Secondly, Ultima Thule is more than 100-times as massive as Comet 67P, so it's rather like comparing something the size of a lunchbox to something the size of a human being. In fact, it would be even more extreme than that." While 67P has a length of 4.1 kilometres (2.5 miles) at its longest, Ultima Thule is roughly 30 kilometres (19 miles). However, other comets have been seen to be bigger than 67P. Halley's Comet, for example, which

> "Comets come from a part of the Kuiper Belt millions of miles away from where Ultima Thule is" **Dr Alan Stern**

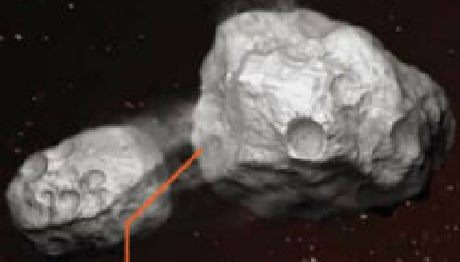
Above: Dr Alan Stern, principal investigator of the New Horizons mission

Below: ESA's Rosetta mission is still revealing secrets about comets three years after its end

© NASA; Nicholas Forder; Maciej Rebisz; E. Kolmhofer, H. Raab; Johannes-Kepler-Observatory, Linz, Austria

Past observations of comets

Observing these space snowballs is a rarity that can tell many tales about the Solar System's past



1P/Halley (Halley's Comet)
Observed by
Soviet Union's Vega 2
Year observed
1986
Dimensions
15 x 8 kilometres
(9 x 5 miles)
Orbital period
75 years
Closest point to the Sun (perihelion)
0.6 AU
Furthest point from the Sun (aphelion)
35 AU

67P/Churyumov-Gerasimenko
Observed by
ESA's Rosetta
Year observed
2014
Dimensions
4 x 4 kilometres
(3 x 3 miles)
Orbital period
6.5 years
Closest point to the Sun (perihelion)
1.2 AU
Furthest point from the Sun (aphelion)
5.7 AU

103P/Hartley (Hartley 2)
Observed by
NASA's Deep Impact
Year observed
2010
Dimensions
1.2 x 1.6 kilometres
(0.8 x 1 miles)
Orbital period
6.5 years
Closest point to the Sun (perihelion)
1 AU
Furthest point from the Sun (aphelion)
5.9 AU

81P/Wild (Wild 2)
Observed by
NASA's Stardust
Year observed
2004
Dimensions
5.5 x 4 kilometres
(3 x 2.5 miles)
Orbital period
6 to 43 years
Closest point to the Sun (perihelion)
1.6 AU
Furthest point from the Sun (aphelion)
5.3 AU

19P/Borrelly (Borrelly's Comet)
Observed by
NASA's Deep Space 1
Year observed
2001
Dimensions
8 x 4 kilometres
(5 x 3 miles)
Orbital period
6.8 years
Closest point to the Sun (perihelion)
1.4 AU
Furthest point from the Sun (aphelion)
5.8 AU

9P/Tempel (Tempel 1)
Observed by
NASA's Deep Impact
Year observed
2005
Dimensions
7.6 x 4.9 kilometres
(4.7 x 3 miles)
Orbital period
5.6 years
Closest point to the Sun (perihelion)
1.5 AU
Furthest point from the Sun (aphelion)
4.7 AU

is approximately half the size of Ultima Thule, and even Comet Hale-Bopp is estimated to be between 30 and 40 kilometres (19 to 25 miles) across.

Even the bi-lobe feature, the striking visual similarity between the two objects, was not formed in the same way. "In the case of Ultima Thule, you can see from the imagery that this is the result of two distinct objects that formed independently, and came to be resting on one another. They underwent a very gentle merger," explains Stern. "In the case of comets, we really don't know that this is a primordial signature because the comets we have observed have evolved by being near the Sun. It's quite likely their shapes and other properties have been very heavily affected by that." Differences in origin, size and formation of the bi-lobial feature means that they are less like brothers but, if you investigate further, they are more like cousins.

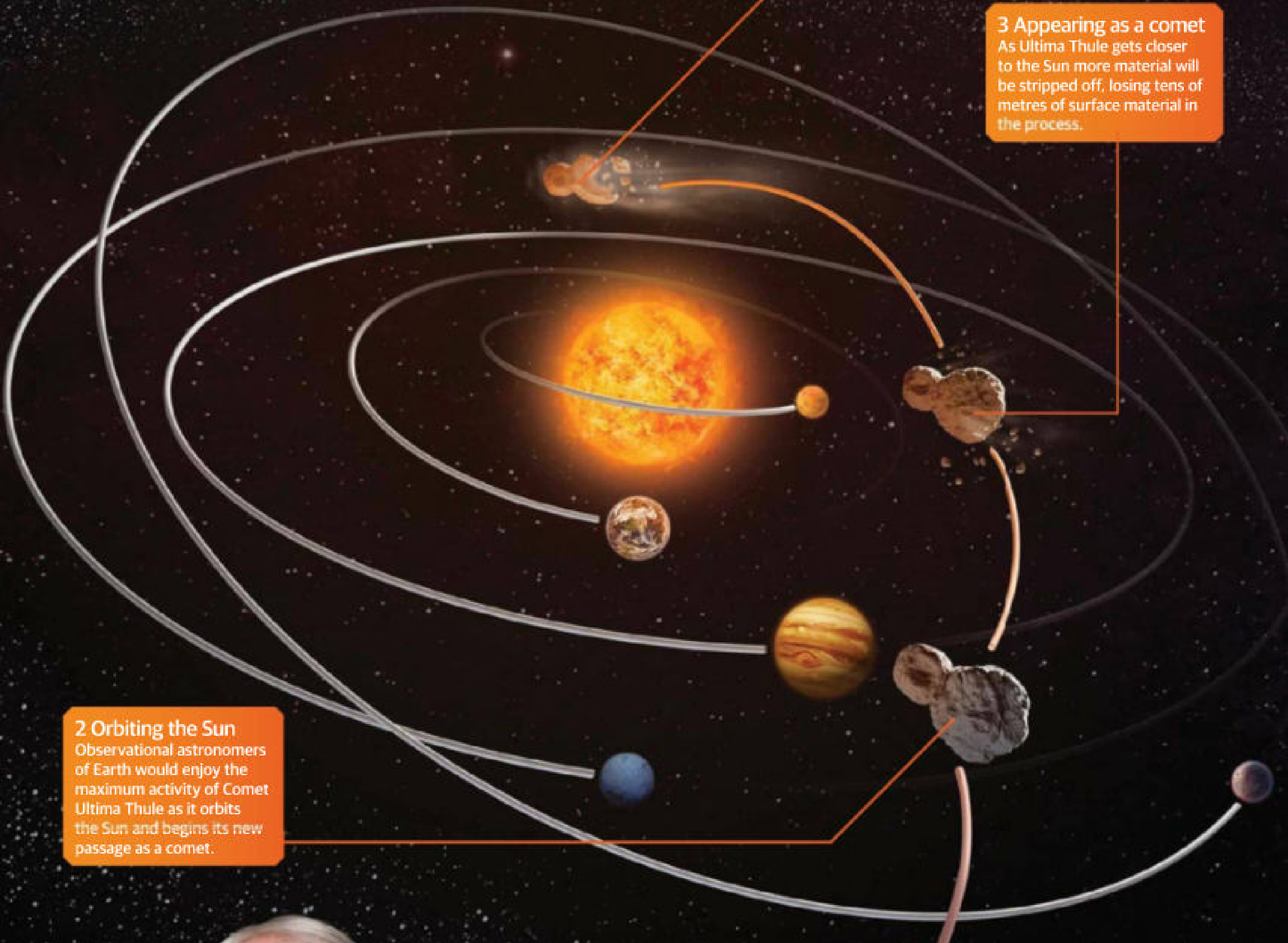
The Solar System is not the same as it was over 4.5 billion years ago. The area around the Sun was a hectic field of clumps of rock and ice known as planetesimals, which were continuously bumping into each other like you would if you were trying to walk through a crowd of people. Each bump meant the planetesimals could collect more mass, and the ones that gathered a substantial amount became the planets we see today. The ones that weren't able to accrete as much became the Solar System's leftovers, including dwarf planets, asteroids, comets, KBOs and others. Although it seems that KBOs and comets could have been similar once upon a time, due to the dynamic and tempestuous nature of the early Solar System they were cast into different orbits, and therefore different lives.

For Ultima Thule, its orbit has been a stable one as it follows the same route around the Sun beyond that of Neptune, and it will continue this path until it returns to the same spot in almost 300 years' time. It has been doing this for billions of years, frozen in the icy realm of the Kuiper Belt where the light from the Sun and surface activity are at a minimal. Comets tend to follow a more elliptical orbit, one that takes them from the Kuiper Belt – and even further – and swoops into the inner Solar System, crossing the path of Jupiter while doing so. Could it be that a change of direction could transform Ultima Thule into a comet?

Right: The Sun heats comets as they approach, causing them to shed their matter as a tail

The journey from KBO to comet

Ultima Thule must undergo a drastic change to become a space snowball, but it is still possible

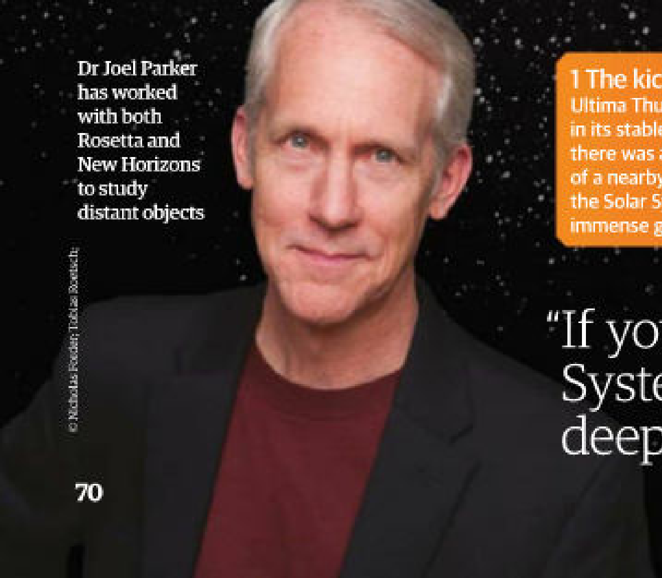


1 The kick-start
Ultima Thule would stay in its stable orbit unless there was a close passing of a nearby star influencing the Solar System with its immense gravity.

2 Orbiting the Sun
Observational astronomers of Earth would enjoy the maximum activity of Comet Ultima Thule as it orbits the Sun and begins its new passage as a comet.

3 Appearing as a comet
As Ultima Thule gets closer to the Sun more material will be stripped off, losing tens of metres of surface material in the process.

4 Passing Jupiter
Jupiter is the next influencer in the Solar System, second to the Sun, and its gravity will determine its future path.



Dr Joel Parker has worked with both Rosetta and New Horizons to study distant objects

© Nicholas Forder; Tobias Roetsch;

> "If you moved it into the inner Solar System, the heat from the Sun would go deep into Ultima Thule" **Dr Joel Parker**

Dr Joel Parker, director of the Southwest Research Institute in the United States who has worked on both the Rosetta and New Horizons missions, seems to think so, as he tells **All About Space**: "Ultima Thule has been in the distant outer Solar System, in cold storage, for its entire life. It likely has lots of ice not too far below the surface and throughout," Parker explains. "If you moved it into the inner Solar System, the heat from the Sun would go deep into Ultima Thule, evaporating those ices, and they would escape as gas, dragging dust with the gas - which is exactly what a comet is."

It's possible that, with a push, Ultima Thule could one day become a comet, and it's not as far-fetched as some may think. It isn't far off scientists' understanding of the dynamical evolution of comets. Comets are essentially objects formed in the cold classical region, or were placed there thanks to the evolution of the Solar System's juggernauts - for example Jupiter and Saturn - and were then knocked into the inner Solar System because of some other event.

What would have to happen to send Ultima Thule hurtling into the Solar System? "Passing stars and galactic tides likely have changed the orbit of much more distant objects in the Oort Cloud, but for something closer in, and in that area of the Kuiper Belt, it would have to be a crazily close passing star, which is very unlikely," says Parker. "This is unlikely because Ultima Thule is obviously in an extremely stable orbit that has kept it in that region of the Solar System for the last 4.5 billion years."

A passing star is a scenario that is extremely unlikely to happen anytime soon, as astronomers would probably notice a huge star bombing towards the Solar System. But if it were, and Ultima Thule was knocked inwards, then it would undergo some drastic changes as soon as it started moving closer. "[Sublimation] could happen at any distance closer than its current orbit. If it were moved closer to the Sun the thermal wave would go deeper, heating ices that have never been heated before. So it could become 'active' - although only slightly - even before it reached the orbit of Neptune," says Parker. "As it got closer it would pass distances where the temperature - based on distance from the Sun - would make any volatile ices near the surface sublimate, for example nitrogen, carbon monoxide, carbon dioxide, and water."

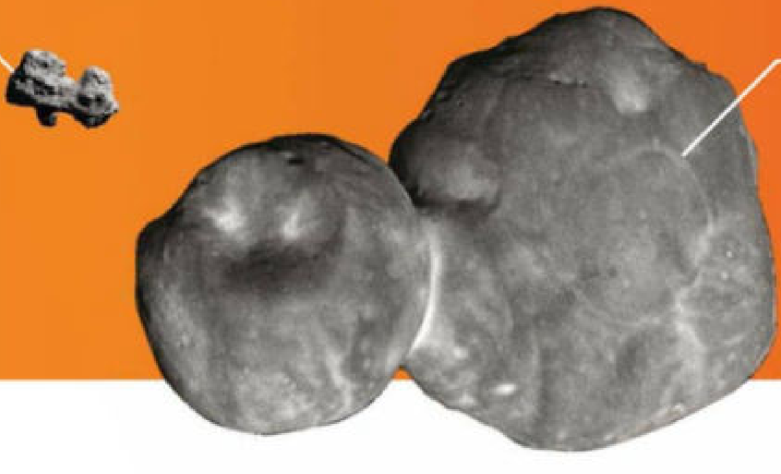
Comets could have brought water to Earth in the past

After passing Neptune it would have to weave past the gas giants, but wouldn't be able to avoid the 'King of the Solar System', Jupiter. Depending on the course of future Ultima Thule, the powerful gravity of Jupiter could affect it in one of three ways: firstly, it could enter the planet's orbit - a similar story to how Neptune got its moon Triton. Secondly, it could avoid being captured and simply be redirected, whether that's into the area where our terrestrial planets reside or slingshotted elsewhere. Or finally, it could be directed into a collision course with Jupiter, just like Comet Shoemaker-Levy 9's demise in 1992. This event saw Comet Shoemaker-Levy 9 torn apart into over 20 pieces due to Jupiter's tidal forces before smashing into the planet with the force of 300 million atomic bombs. Scientists estimated that Comet Shoemaker-Levy 9 was no bigger than two kilometres (1.2 miles) in size.

Nonetheless, the comet version of Ultima Thule would undergo rapid changes as the influence of the Sun became more and more apparent. If it were to enter an orbit similar to 67P, then it would most likely lose material at a similar rate, meaning that approximately ten metres (33 feet) of surface material would be stripped off the object per orbit. With an object the size of Ultima Thule, it would definitely make a great sight for observational astronomers who love photographing comets. Then again, there would also have be a huge star flying past the Solar System at the same time!

Ultima Thule vs Comet 67P/Churyumov-Gerasimenko

Although they share a bi-lobial appearance, what are their differences?



Comet 67P
Object classification
Comet
Region of origin
Scattered disc,
Trans-Neptune region
Length
4 kilometres (3 miles)
Surface features
Clear sublimation,
water vapour escaping
the surface,
moving boulders

Ultima Thule
Object classification
Kuiper Belt Object
Region of origin
Cold classical region,
Kuiper Belt
Length
30 kilometres (19 miles)
Surface features
Clear contact binary
object, craters, areas of
high reflectivity

ASK Space

Our experts answer your questions

Did you know?

Telescopes can view wavelengths of light invisible to human eyes - combining these can create images of nebulae showing a rainbow of colour

ASTROPHYSICS

How does a cloud of gas and dust become a star?

Our Milky Way galaxy is filled with interstellar gas peppered with dust, known together as the interstellar medium. This very low-density material churns with turbulent motion between stars, and most of it can remain in this free-moving form for millions or even billions of years. Where pockets of gas become compressed, sometimes through the pressure from a nearby supernova explosion, the density can rise to the point where the inward gravitational pull of the gas on itself is a stronger influence than the dispersing tendency of turbulence. This interstellar cloud can therefore be gravitationally bound, at least for a while.

Through an interplay of the motions within the interstellar cloud, internal gravitational pull and magnetic fields, the cloud can collapse into unstable, long filaments stretching between dense 'hubs' - cloud cores that can further collapse into clusters of dense cores. If a core has enough mass in a small enough volume, the gravitational pull can condense the gas into a hot, spherical 'protostar'. Material from the surrounding cloud will continue to accrete onto this protostar via an intermediate passage through a circumstellar disc. Eventually enough mass and pressure accumulate to ignite the process of fusion in the central region, creating a fully born star. Stars much more massive than our Sun emit powerful photons that can ionise the remaining gas surrounding the stellar nursery. This brightly coloured gas comprises the colourful nebulae that we now know are not only beautiful, but also signposts of active star formation.

Jennifer Wiseman is the senior project scientist for the Hubble Space Telescope

Newly formed stars illuminate surrounding gas and dust to create nebulae

Mars' moons show an unusual combination of circular orbits and non-Martian composition

MOONS

Where did Mars' moons come from?

The origin of Mars' two moons, Phobos and Deimos, is a mystery. We once thought that these moons were asteroids captured by Mars' gravity. On first inspection their small sizes - Phobos is only 27 kilometres (17 miles) along its longest axis, while Earth's Moon has an average diameter of 3,500 kilometres (2,200 miles) - irregular shapes and non-Martian composition suggested an asteroidal origin. However, a capture scenario tends to produce moons with highly eccentric orbits. Phobos and Deimos are in nearly circular orbits.

An alternative explanation is that the two moons formed around Mars following a giant-impact scenario. Similar to our understanding of the formation of Earth's Moon, a giant impact could have led to the formation of a disc of debris around Mars. Material in this debris gradually coalesced to form the two moons we see today.

However, many questions still remain, such as why the material on these two moons looks distinctly unlike that of Mars. In an attempt to end this debate, the Japanese Space Agency developed the Martian Moons eXploration (MMX) mission, which will launch in the early 2020s. It will travel to one of these moons, collect a sample and return it to Earth. Laboratory analysis of this sample may finally resolve these questions, and likely introduce new clues and questions for how our Solar System formed.

Ronald Ballouz is a postdoctoral researcher at Japan Aerospace Exploration Agency (JAXA)'s Institute for Space and Astronautical Studies

SPACE EXPLORATION

Will teleportation ever be possible for humans?

If an object is teleported according to quantum physics laws, it has to be considered a quantum object. Instead we might ask if it could be possible to teleport large macroscopic objects.

A common misconception is that in quantum teleportation, particles disappear in one place and reappear somewhere else – just like television taught us. However, in quantum teleportation the state of the system gets undefined for one object but reappears on another object. At first this might sound less exciting, but in my opinion it is equally astonishing and, moreover, it will be a key element for a future quantum internet.

Say you can transport all properties, a philosophical question arises: if we are able to teleport every single property of an object to another one, and the second object now resembles the first in every aspect, haven't we actually teleported the object?

Coming back to the original question. Quantum teleportation relies on entanglement, one would need to entangle all properties of the macroscopic object simultaneously. Theoretically there is nothing known that would forbid it; however, this task would be extremely challenging. Nonetheless, history repeatedly showed us that one should never underestimate the creativity of future scientists, so I think only time can give us a proper answer.

Robert Fickler is an experimental quantum physicist working at the Laboratory of Photonics of the Tampere University in Finland

Theoretically teleportation could be possible, but it is much more complicated than quantum teleportation

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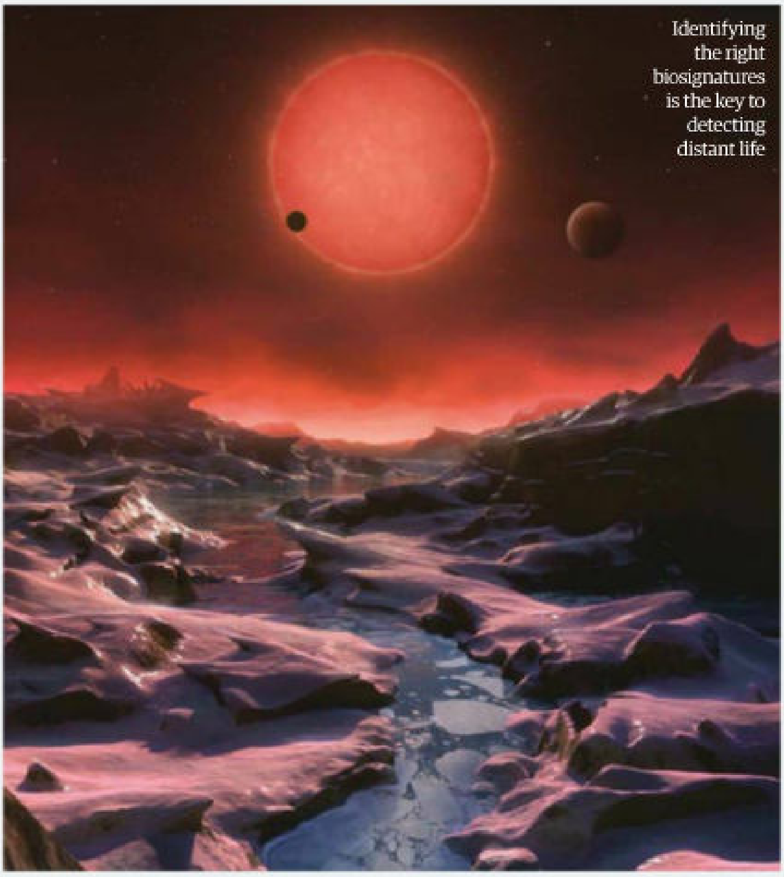
ASK Space

Our experts answer your questions

EXOPLANETS

When searching for life outside of our Solar System, what are the key signs to look for?



Identifying the right biosignatures is the key to detecting distant life

We are looking for signatures of living processes that can be detected from interstellar distances. In order for a molecule to be a potential biosignature gas, it has to fulfil three key criteria: firstly, it must interact with light in such a way that we can see its molecular fingerprint embedded in the light reflected, emitted or transmitted by a distant planet's atmosphere. It has to build up to detectable concentrations, so it has to survive photochemical reactions in the atmosphere, and it has to be specifically biological - in other words, it must be difficult or impossible for processes to create it.

A key example of a potential biosignature gas is molecular oxygen (O_2) made by photosynthetic bacteria, algae and plants on Earth. Even more convincing than one gas alone would be multiple biogenic gases in 'thermodynamic disequilibrium'. This means that the gases would otherwise destroy each other over time, so they must be replenished by a continuous source. Some examples of potentially biogenic gases we'd like to see include methane, nitrous oxide, methyl chloride and even molecular nitrogen in contact with a surface ocean, which may be inferred by the presence of water vapour.

Eddie Schwieterman is a NASA postdoctoral program fellow at the University of California Riverside

Did you know?

Planck was a European Space Agency (ESA) probe launched in May 2009 to study the cosmic microwave background

COSMOLOGY

Did the Big Bang actually make a noise?

Modern cosmology tells us that the universe started 13.8 billion years ago as a point-like source [or singularity] that expanded, exponentially at first, into the cosmos we know today. It is perhaps not surprising that the Big Bang, the mother of all explosions, made a sound. We know this from measurements of the cosmic microwave background (CMB) made by the WMAP and Planck space missions.

Just after the Big Bang, all the matter in the universe was a super-hot plasma confined to the relatively small space of the emerging universe. In that closed space there were vibrations, sound waves of compression and rarefaction that propagated throughout the plasma. The sound persisted as the universe expanded. About 300,000 years after the Big Bang, the cooling and expanding universe reached the point where electrically neutral hydrogen atoms could form from the free electrons and protons of the hot plasma. When this happened, light, which had been trapped by the electrical charges of the plasma, could pass freely through the neutral hydrogen, and the universe went from opaque to transparent. That released light, which reaches us today as microwaves, has recorded in it the sound waves that were present when it was formed.

In 2003 with WMAP data and again in 2013 with Planck data, I was able to take the sound-wave frequencies and render them as audible sound waves so that we can hear the sound of the Big Bang with our own ears.

John G. Cramer is Professor Emeritus in physics at the University of Washington (UW) in Seattle, United States

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Dark energy and dark matter make up 95 percent of the universe

ASTROPHYSICS

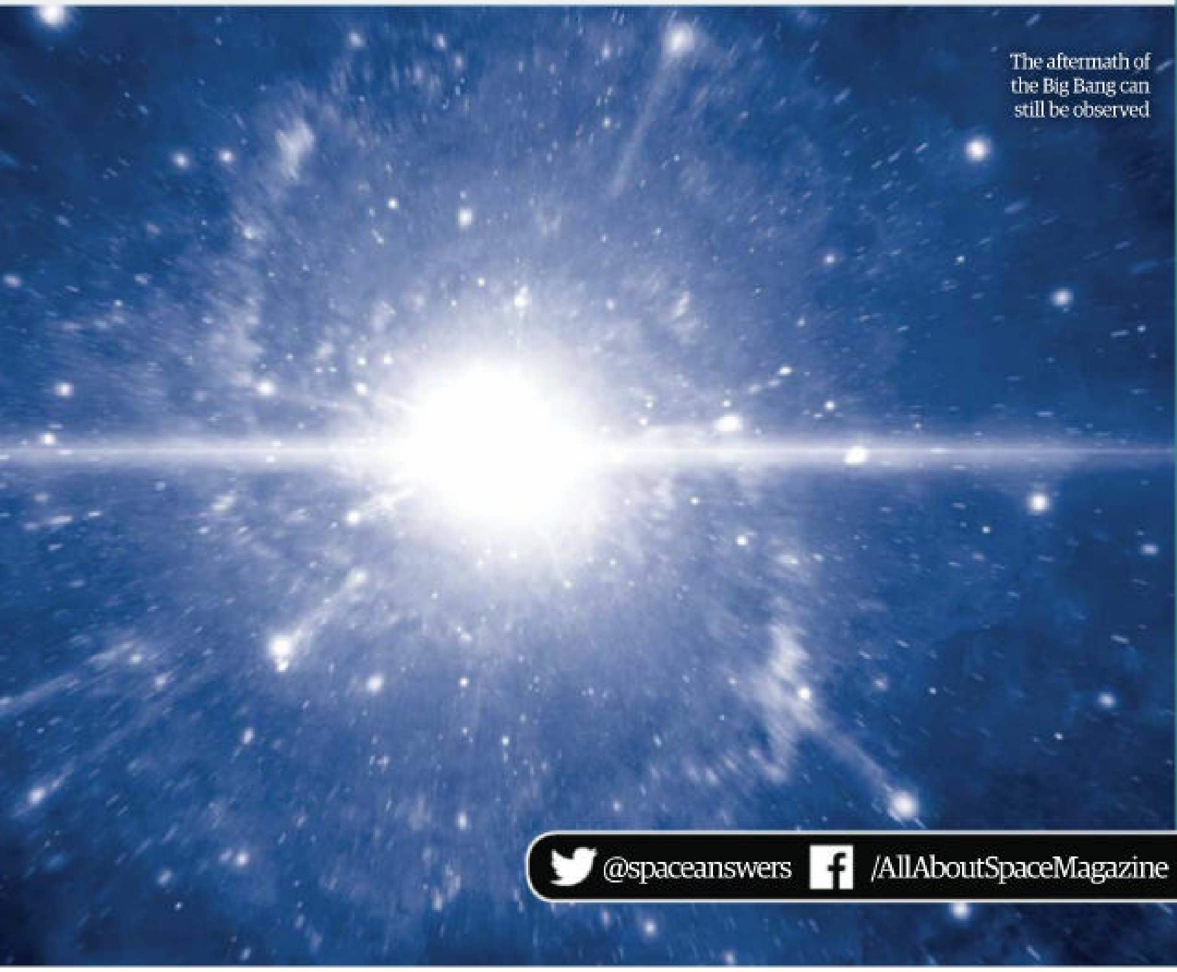
Will we ever discover dark matter and dark energy?

Of course we will. We're just not there yet. Dark matter is particularly frustrating because we have been looking for it for decades now and have come up empty-handed.

Most astronomers are convinced it's out there, but we don't know what it's made of. We see how it influences matter around it, for example, by holding galaxies together, but it has to be made of a new kind of fundamental particle that we have not yet discovered. Dark energy is more baffling and we know less about it, but we will get there eventually. There is even the remote possibility that neither dark matter or dark energy exists. In this case, what we need to do is modify Einstein's theory of gravity to account for this behaviour at large distances, more pull at galactic scales and antigravity at even greater scales to explain the accelerating expansion of the universe.

Just don't mention this to people working in the field of dark matter and energy! They understandably get very upset with the suggestion that they are chasing ghosts.

Jim Al-Khalili is a popular science communicator and professor of physics at the University of Surrey, United Kingdom



The aftermath of the Big Bang can still be observed

SPACE EXPLORATION

What will Japan's spacecraft do on the new mission to Mercury?

Mio, formerly known as the Mercury Magnetospheric Orbiter (MMO), is the craft that focuses on the magnetic-oriented science of the mission. It will observe the magnetic field of Mercury and see how it interacts with the solar wind, the supersonic flow of ionised gas from the Sun.

For this purpose, on board Mio are electromagnetic field instruments, plasma particle detectors and an imaging device for the thin atmosphere that Mercury has.

Mio is a fast-spinning spacecraft that has strong advantages in making magnetic-oriented observations. ESA's Mercury Planetary Orbiter (MPO) has a three-axis stabilised attitude which is the best for imagery observations, but also measures the magnetic field. There will be two-point measurements of the magnetic field available from BepiColombo as a whole, and this provides a strong advantage in analysing the structure of the swift planet's exceedingly intrinsic magnetic field.

Professor Masaki Fujimoto is project scientist of Mio as part of the BepiColombo mission

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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What's in the sky?

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

23 MAY

The Moon and Pluto make a close approach, passing within 0°04' of each other in Sagittarius

© NASA/JPL-Caltech

29 MAY

Dwarf planet Ceres reaches opposition in Ophiuchus, glowing at magnitude 7.0

4 JUN

Globular cluster Messier 12 is well placed in Ophiuchus at magnitude 6.1

12 JUN

Globular cluster Messier 92 is well placed for observation in Hercules, glowing at magnitude 6.5

© ESA/Hubble & NASA

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16 JUN

The Moon and Jupiter make a close approach, passing within 1°58' of each other in Ophiuchus

17 JUN

Mercury reaches its highest point in the evening sky, shining at magnitude 0.4

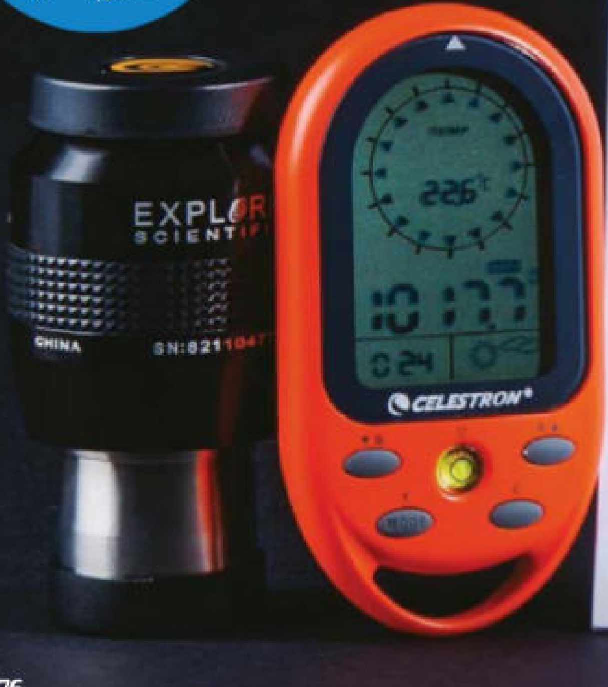
Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope

19 JUN

Conjunction between the Moon and Saturn in Sagittarius

19 JUN

The Moon and Saturn make a close approach, passing within 0°26' of each other in Sagittarius



Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

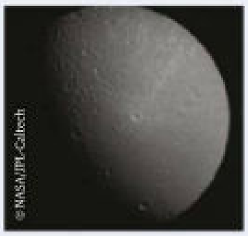
3 JUN

Globular cluster Messier 13 is well placed for observation in Hercules at magnitude 5.8

16 JUN

Conjunction between the Moon and Jupiter in Ophiuchus

© ESA/Hubble and NASA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18 JUN

Mercury reaches half phase (dichotomy), shining brightly at magnitude 0.1

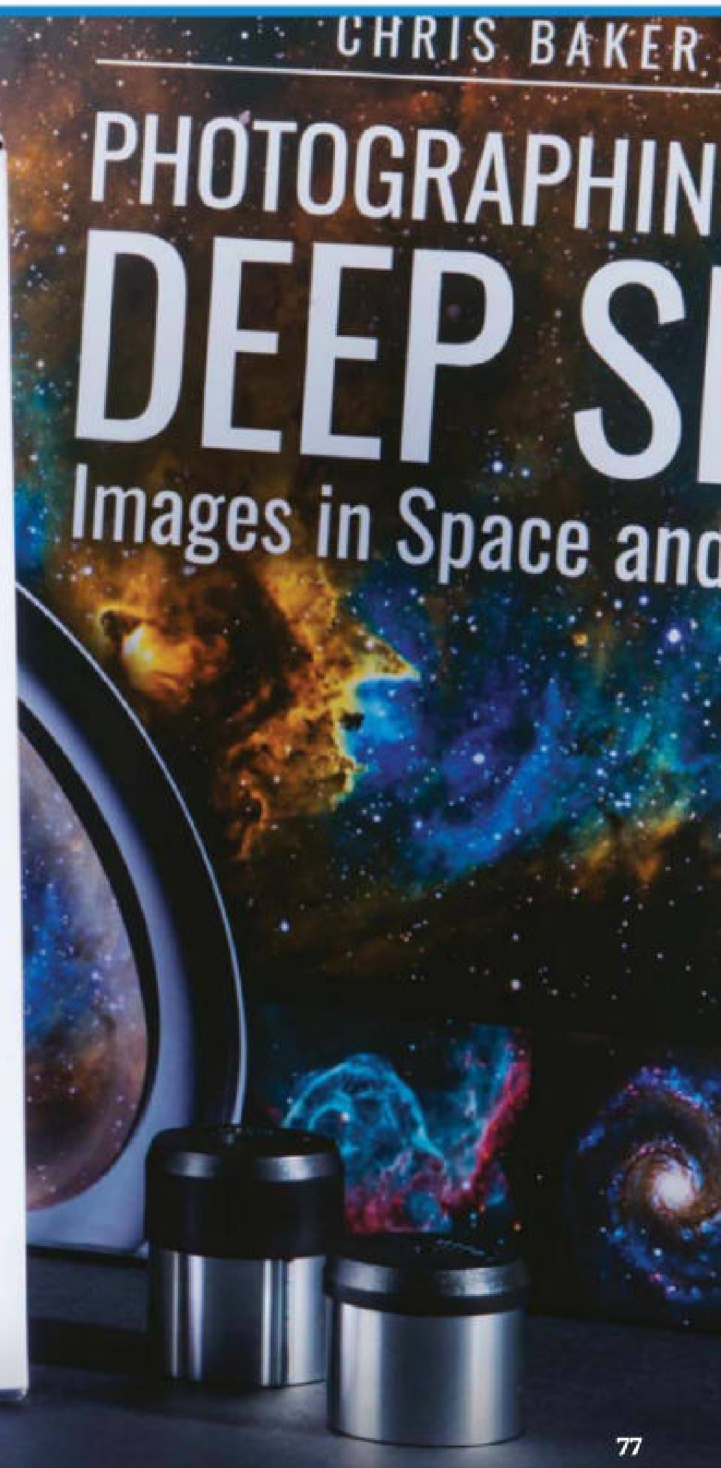
19 JUN

Open star cluster IC 4665 is well placed for observation in Ophiuchus, glowing at magnitude 4.2

19 JUN

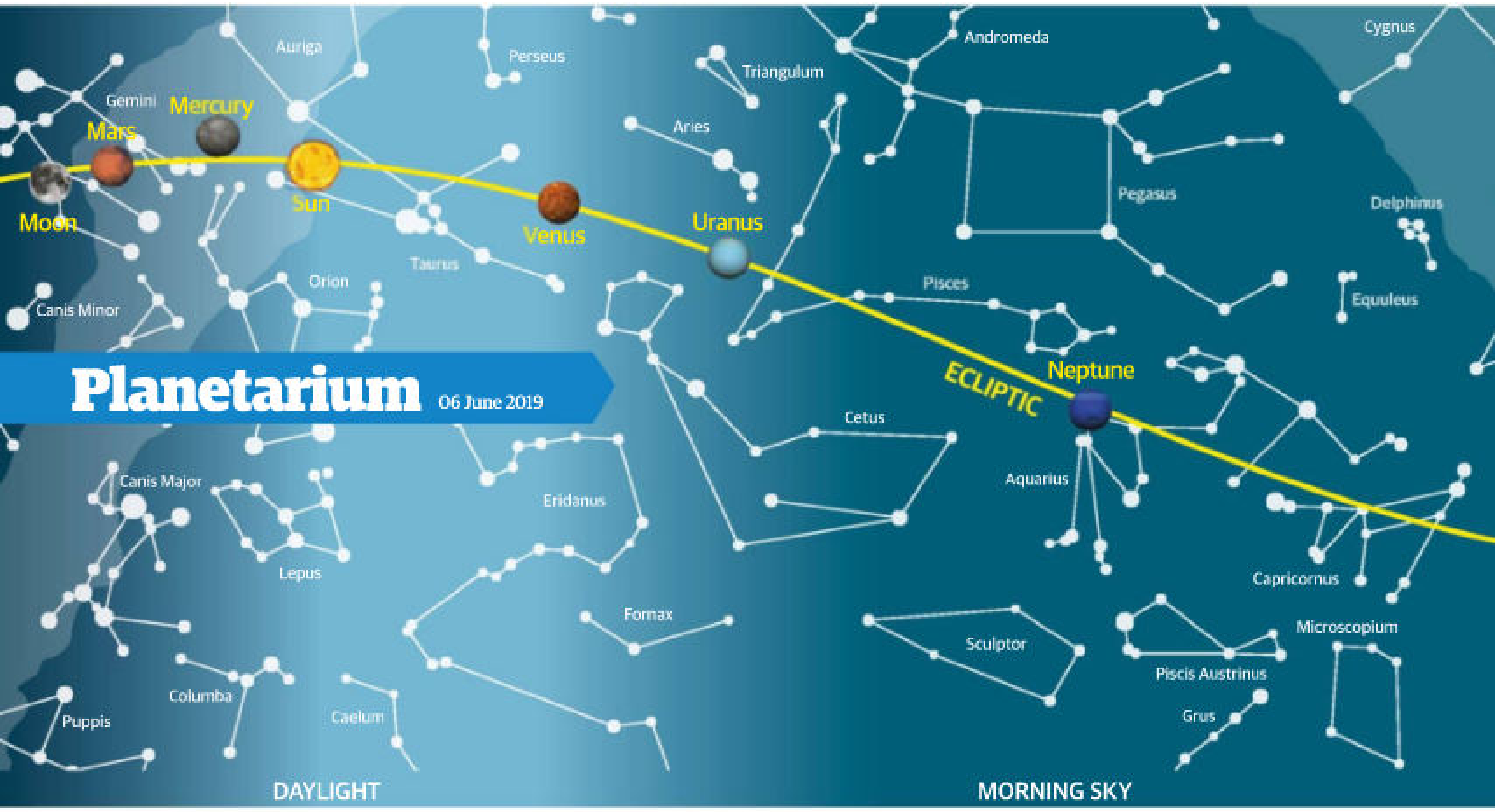
The Moon and Pluto make a close approach, passing within 0°03' of each other in Sagittarius

© Roberto Mura



Planetarium

06 June 2019



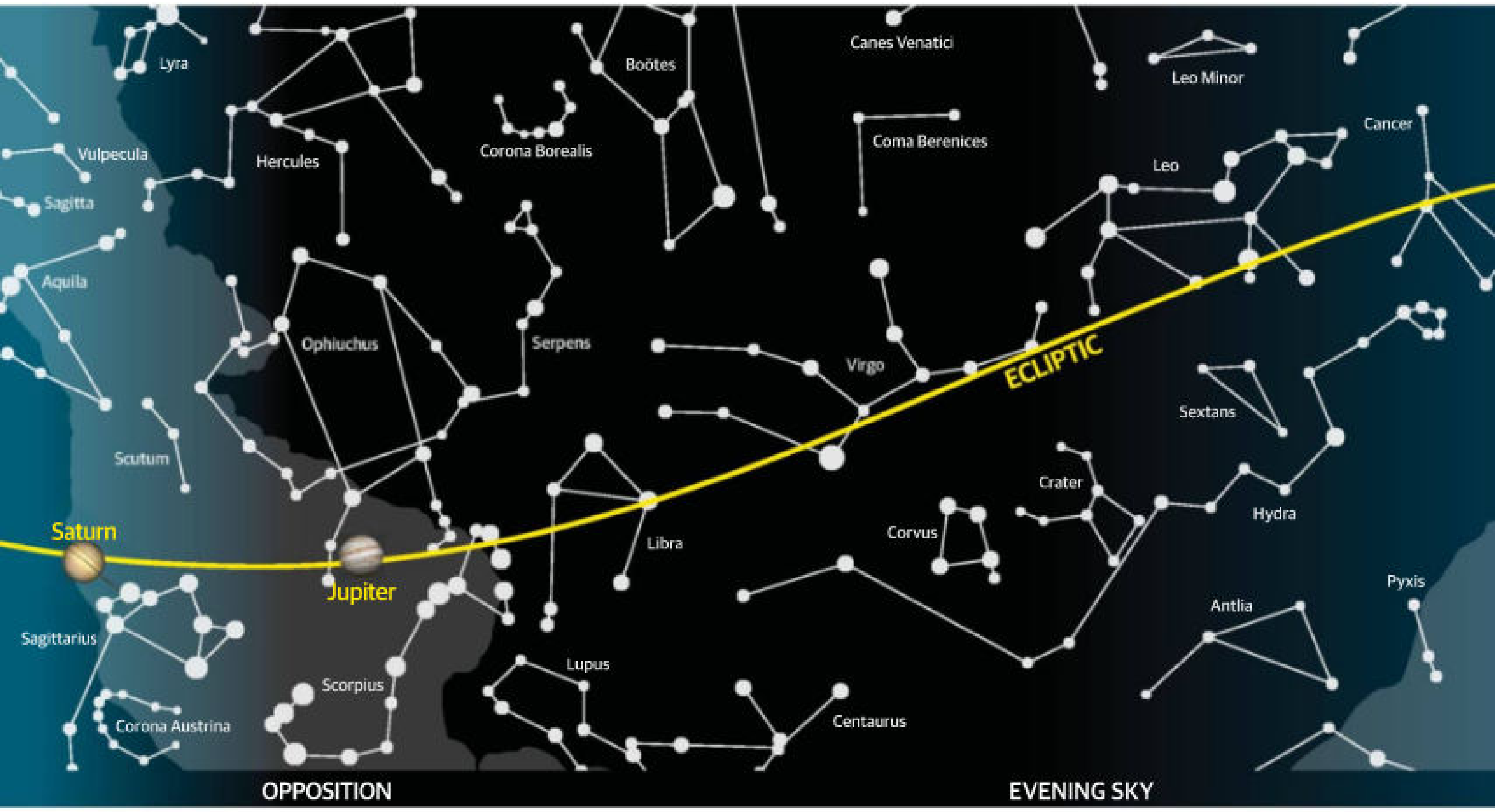
Moon calendar

* The Moon does not pass the meridian on 16 June

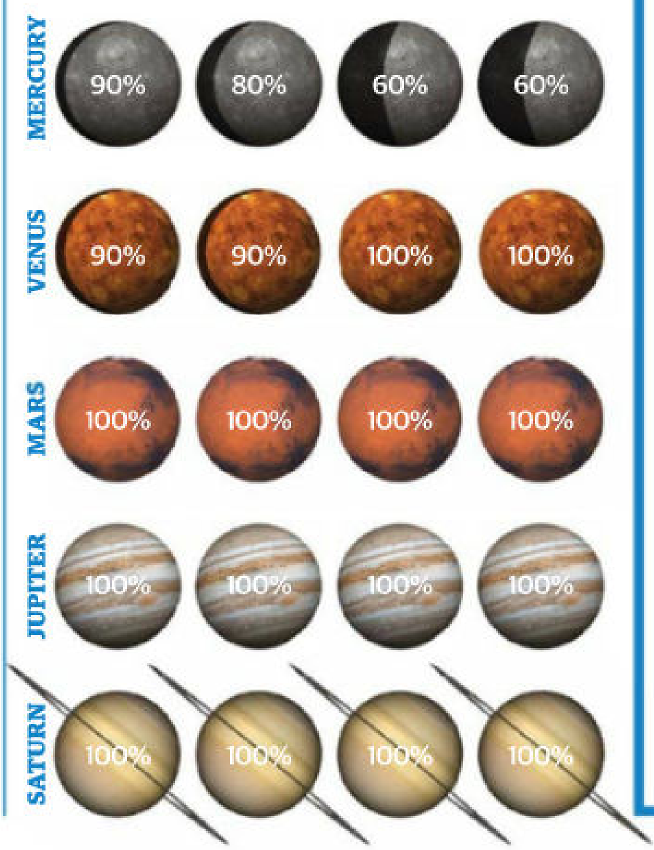
23 MAY		81.5%	◓00:32	◒09:52
24 MAY		73.1%	◓01:13	◒09:52
25 MAY	TQ	63.9%	◓01:46	◒10:55
26 MAY		54.3%	◓02:14	◒12:00
27 MAY		44.5%	◓02:37	◒13:05
28 MAY		34.9%	◓02:57	◒14:11
29 MAY		25.8%	◓03:16	◒15:17
30 MAY		17.5%	◓03:35	◒16:25
31 MAY		10.3%	◓03:55	◒16:25
1 JUN		4.7%	◓04:17	◒18:47
2 JUN		1.2%	◓04:43	◒20:01
3 JUN	NM	0.1%	◓05:14	◒21:14
4 JUN		1.6%	◓05:54	◒22:23
5 JUN		5.9%	◓06:45	◒23:33
6 JUN		12.8%	◓07:47	◒--:--
7 JUN		21.9%	◒00:14	◓08:58
8 JUN		32.7%	◒00:54	◓10:16
9 JUN		44.3%	◒01:27	◓11:35
10 JUN	FQ	56.2%	◒01:54	◓12:55
11 JUN		67.6%	◒02:18	◓14:13
12 JUN		77.9%	◒02:40	◓15:31
13 JUN		86.6%	◒03:02	◓16:47
14 JUN		93.3%	◒03:26	◓18:03
15 JUN		97.8%	◒03:52	◓19:17
16 JUN		--.--*%	◒04:24	◓20:27
17 JUN	FM	99.8%	◒05:01	◓21:30
18 JUN		99.5%	◒05:47	◓22:25
19 JUN		97.0%	◒06:39	◓23:10
20 JUN		92.6%	◒07:38	◓23:47

%	Illumination
◓	Moonrise time
◒	Moonset time
FM	Full Moon
NM	New Moon
FQ	First quarter
LQ	Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	30 MAY	6 JUN	13 JUN	20 JUN
MERCURY	90%	80%	60%	60%
VENUS	90%	90%	100%	100%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	23 May	04h 03m 56s	+21° 21' 19"	Taurus	-2.3	04:58	21:03
	30 May	05h 08m 08s	+24° 30' 00"	Taurus	-1.3	05:12	22:02
	06 Jun	06h 08m 20s	+25° 30' 07"	Gemini	-0.7	05:37	22:42
	13 Jun	06h 59m 30s	+24° 41' 11"	Gemini	-0.2	06:07	22:59
	20 Jun	07h 39m 36s	+22° 42' 12"	Gemini	0.2	06:34	22:57
VENUS	23 May	02h 28m 17s	+13° 04' 21"	Aries	-3.9	04:13	18:37
	30 May	03h 01m 38s	+15° 46' 15"	Aries	-3.9	04:04	18:58
	06 Jun	03h 35m 51s	+18° 09' 33"	Taurus	-3.9	03:56	19:19
	13 Jun	04h 10m 58s	+20° 10' 13"	Taurus	-3.9	03:51	19:40
	20 Jun	04h 46m 56s	+21° 44' 34"	Taurus	-3.9	03:48	19:58
MARS	23 May	06h18m 20s	+24° 30' 35"	Gemini	1.7	06:50	23:40
	30 May	06h 38m 06s	+24° 18' 12"	Taurus	1.8	06:44	23:30
	06 Jun	06h 57m 43s	+23° 56' 37"	Gemini	1.8	06:38	23:20
	13 Jun	07h 17m 09s	+23° 26' 05"	Gemini	1.8	06:34	23:08
	20 Jun	07h 36m 22s	+22° 46' 58"	Gemini	1.8	06:30	22:55
JUPITER	23 May	17h 23m 07s	-22° 33' 03"	Ophiuchus	-2.6	22:19	06:20
	30 May	17h 19m 34s	-22° 30' 21"	Ophiuchus	-2.6	21:48	05:50
	06 Jun	17h 15m 48s	-22° 27' 16"	Ophiuchus	-2.6	21:16	05:19
	13 Jun	17h 11m 57s	-22° 23' 51"	Ophiuchus	-2.6	20:44	04:48
	20 Jun	17h 08m 09s	-22° 20' 16"	Ophiuchus	-2.6	20:13	04:17
SATURN	23 May	19h 25m 36s	-21° 36' 07"	Sagittarius	0.3	00:19	08:29
	30 May	19h 24m 23s	-21° 38' 58"	Sagittarius	0.3	23:46	08:00
	06 Jun	19h 22m 55s	-21° 42' 20"	Sagittarius	0.2	23:18	07:30
	13 Jun	19h 21m 12s	-21° 46' 09"	Sagittarius	0.2	22:49	07:01
	20 Jun	19h 19m 18s	-21° 50' 18"	Sagittarius	0.2	22:20	06:31

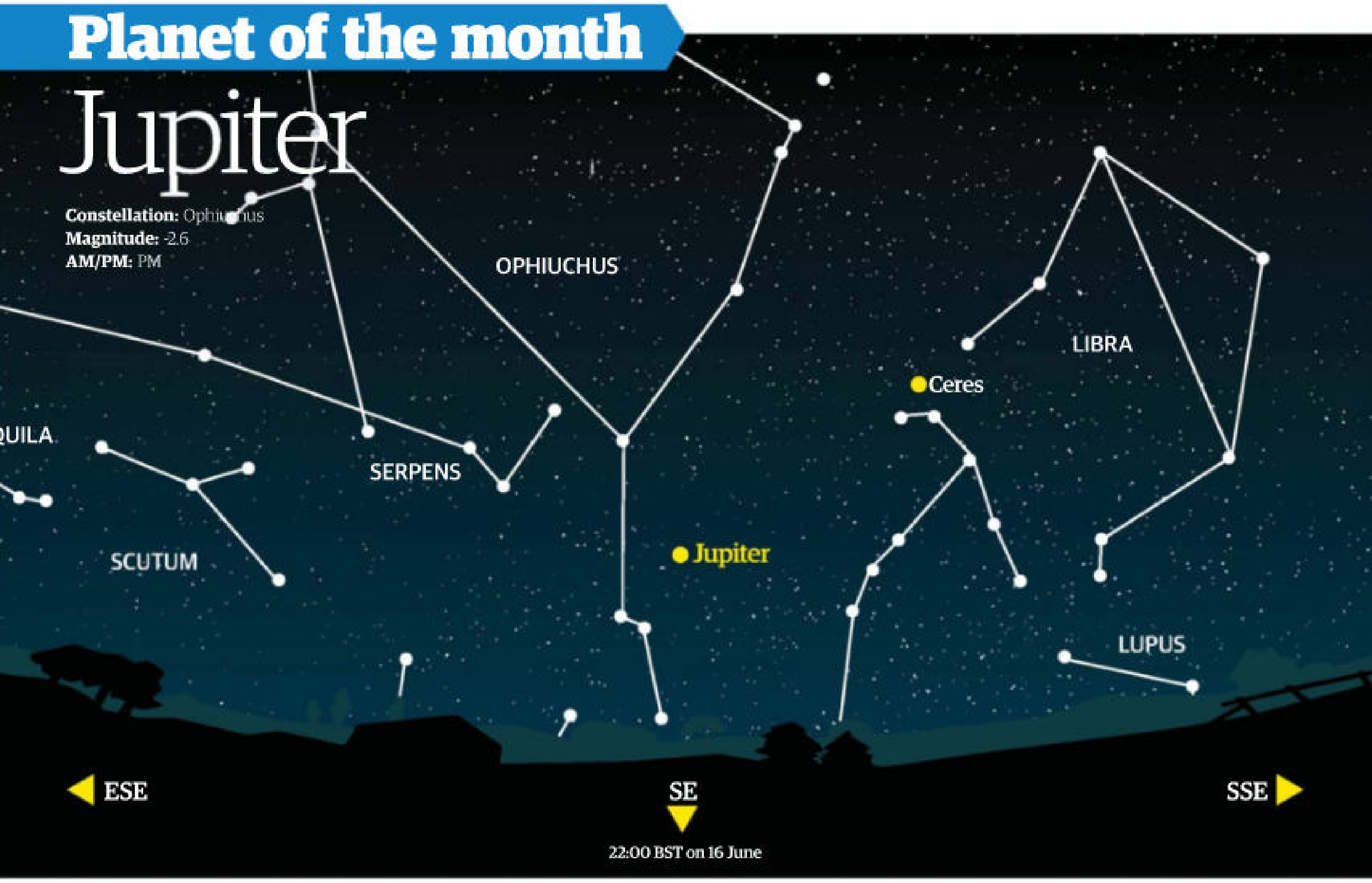
This month's planets

The King of the Solar System reaches opposition this June, ruling the skies all through the evening and until dawn

Planet of the month

Jupiter

Constellation: Ophiuchus
Magnitude: -2.6
AM/PM: PM



22:00 BST on 16 June

Without a shadow of doubt, this month's late-evening sky belongs to Jupiter. This bloated gas giant world – so enormous Earth could fit across its face a dozen or so times, and fit inside it over a thousand times with some room to spare – will look like a strikingly bright electric blue-white spark in the sky to the naked eye, far brighter than any other star or planet in the sky – though technically Venus will be brighter, it will be dimmed a great deal by its proximity to the Sun in the sky this month.

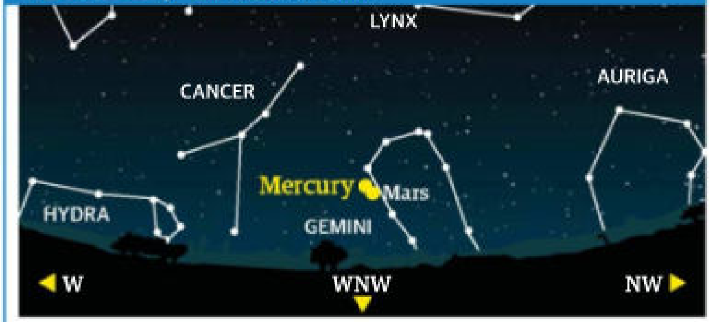
If you have a pair of binoculars you'll see that Jupiter isn't alone. Look at it through binoculars on any clear night and you'll see some tiny pin-prick stars very close to it, up to four on some nights. These 'stars' are actually the four largest and brightest of greedy Jupiter's extended family of 79 moons, and the number you will see at any time will depend on when you're looking: you might see two, three or even four in a variety of different arrangements – all four on one side of Jupiter, or a pair on either side, or a single moon on one side of the planet and a trio of moons on the other. If you want to know which star is which moon any good astronomy or planetarium app for your mobile device will tell you.

Through a telescope you'll be able to see Jupiter's disc, flattened down slightly at its poles because of its rapid spin. Even a small telescope will have enough magnification to show you a couple of dark bands of cloud across Jupiter's light disc, and large instruments reveal its face is dotted and decorated with many fascinating ovals and streaks of cloud, including the famous Great Red Spot, a storm system larger than the Earth itself.

If you want to see Jupiter in the sky this month you won't really have to look for it – it will be so bright you won't need to look for it as it will stand out starkly against the background stars of Ophiuchus as it blazes in the sky. Rising a good hour and a half before midnight, it will dominate the sky right through the night until the approach of dawn makes the sky too bright to see it.

In mid-June this behemoth of a planet will have company in the sky. On the evening of 16 June the almost-full Moon will be shining just 11 degrees to its upper right, and 24 hours later, on the 17th, the full Moon will lie less than three degrees – or six Moon widths – away from it, to its upper left. The pair will make a lovely sight through a pair of binoculars as they sink into the west together just before sunrise

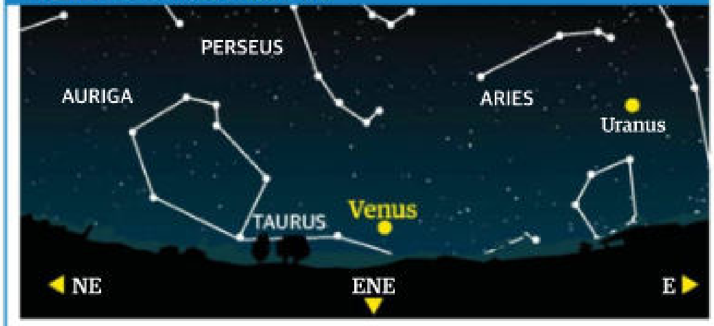
Mercury 22:00 BST on 19 June



Constellation: Taurus into Gemini
Magnitude: -0.9
AM/PM: PM

June is the best time to see Mercury in the evening sky this year. As May ends it will be setting just a few minutes after the Sun, but as June progresses the closest world to the Sun will pull away from it in the sky until it is visible as a bright golden spark low in the northwest through the month.

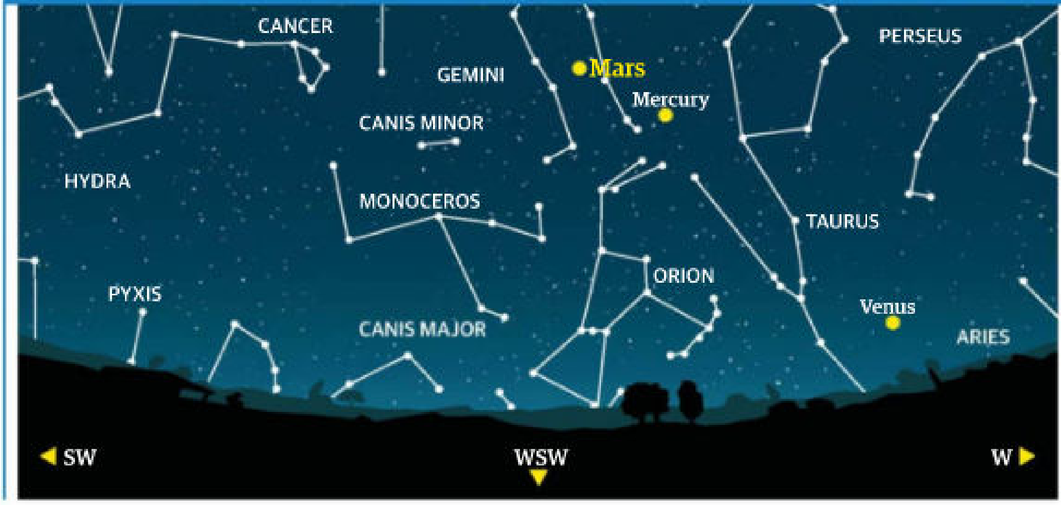
Venus 04:20 BST on 14 June



Constellation: Aries
Magnitude: -3.9
AM/PM: AM

Unfortunately Venus will be so close to the Sun in the sky - and so low in the sky too - that it will be very hard to see. You might need a pair of binoculars to pick it out from the bright background sky, and you'll need to have a low, uncluttered horizon to have any hope of spotting it at all.

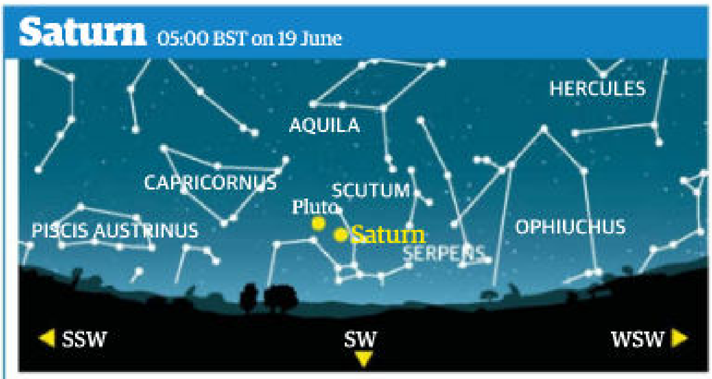
Mars 18:20 BST on 5 June



Constellation: Gemini
Magnitude: 1.7
AM/PM: PM

Mars is an easy naked-eye object in the evening sky during this issue's observing period, looking like an orange star roughly the same brightness as Polaris, the Pole Star, shining below the brighter twin stars of Gemini, Castor and Pollux. Mars will be visible as soon as the sky darkens, setting an hour and a half or so after the Sun. Mars will have lots of company this month. Look for a lovely crescent Moon just four degrees to the left of the Red Planet on 5 June. Then, in mid-June, Mars will have a close encounter with Mercury; on the evening of 18 June they will be at their closest.

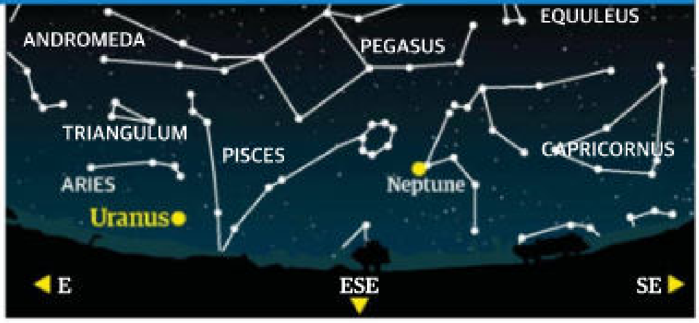
Saturn 05:00 BST on 19 June



Constellation: Sagittarius
Magnitude: 0.3
AM/PM: AM

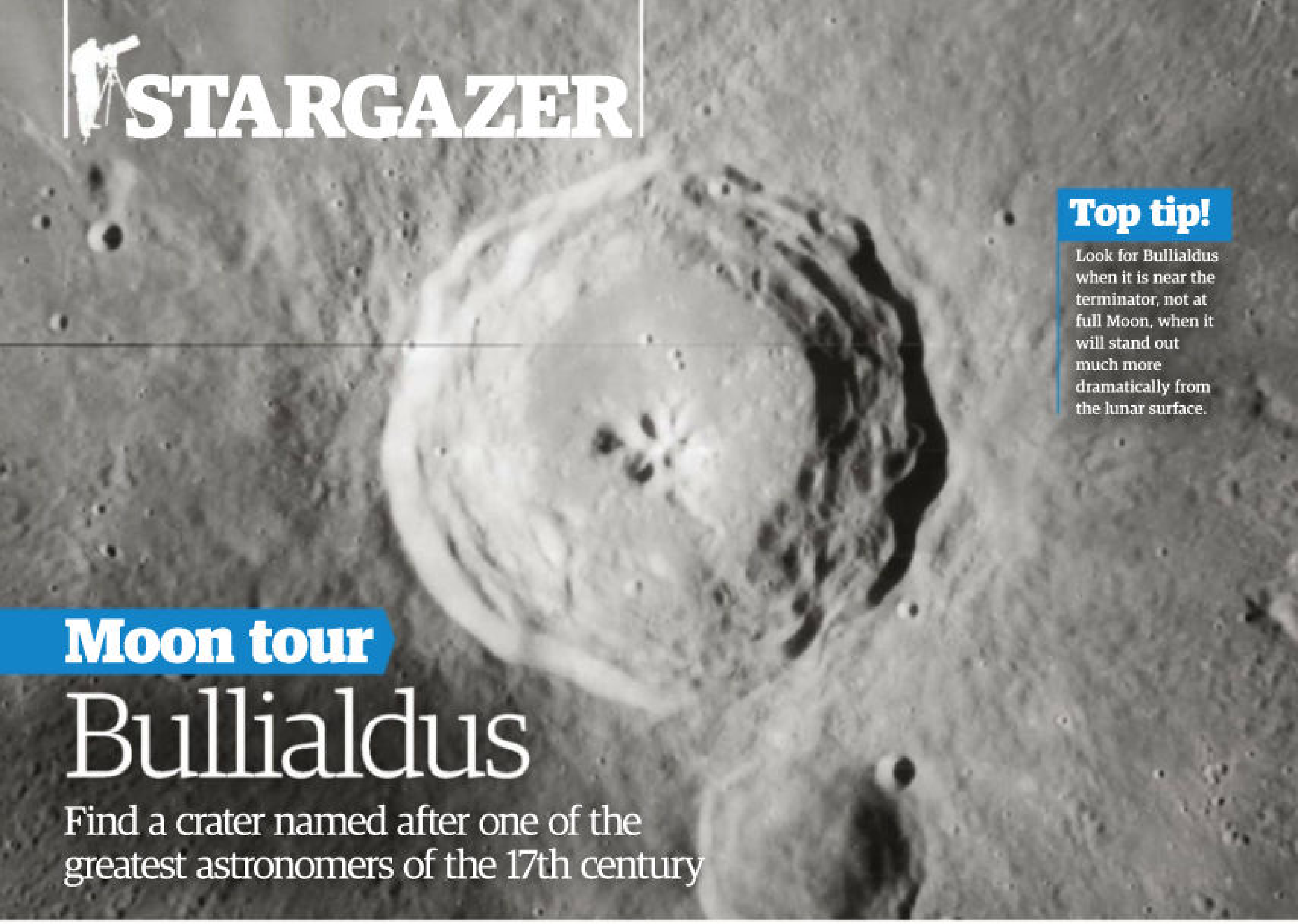
Saturn will be a bright 'star' low in the morning sky during this month, following much brighter Jupiter up and away from the southeastern horizon in the hours before dawn. However, it rises so late that you will only be able to see it for a few hours before the brightening sky washes its pale yellow-white light away.

Uranus 03:00 BST on 20 June



Constellation: Aries
Magnitude: 5.9
AM/PM: AM

At the start of our observing period Uranus is too close to the Sun and too low in the sky to be seen well. However, by the middle of June it will have pulled away from the Sun and appear higher and in a darker sky too, rising an hour and a half before it, so it will be worth a try if you are determined to see it.



Top tip!

Look for Bullialdus when it is near the terminator, not at full Moon, when it will stand out much more dramatically from the lunar surface.

Moon tour

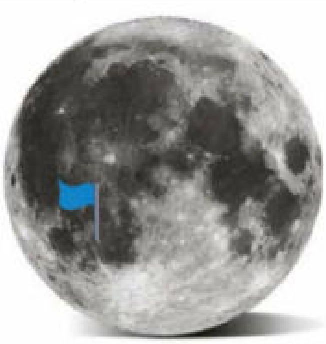
Bullialdus

Find a crater named after one of the greatest astronomers of the 17th century

The giant craters on the Moon are named, appropriately, after the giants of astronomy and science. Blasted out of the Moon's crust by the incredibly violent impacts of asteroids and even larger objects, thousands of great, gaping pits with steep walls and mountains in their centres bear the names of legends such as Copernicus, Tycho, Kepler and many more. It's a pretty safe bet that if you flick your eyes down any list of names at the back of a book detailing the history of astronomy and pick one, just at random, any stargazer who contributed to the increase of our astronomical knowledge and our understanding of our place in the universe, you'll find they have been immortalised on the surface of the Moon with a crater named in their honour. Many names you'll know; many you won't. Bullialdus crater is named after one in the latter group.

Ismaël Bullialdus was one of the most famous astronomers of the 17th century. Living and working in France, he was born in 1605, just five years before Galileo turned his first crude telescope on the night sky, stared wide-eyed at moons in orbit around Jupiter, ranges of jagged mountains on the Moon and a myriad of stars his naked eye could not see on even the clearest, darkest night, and revolutionised our view of the universe. He went on to publish five important books on astronomy and was a member of the 'Republic of Letters', a 17th century group for intellectuals whose members exchanged letters and ideas. He corresponded with such titans as Galileo, Huygens and Fermat, and was an enthusiastic supporter of the revolutionary work of Galileo, Copernicus and Kepler. So it's only fair there's a crater on the Moon named after him, I'm sure you'll agree.

Bullialdus can be found near the western shore of Mare Nubium, the 'Sea of Clouds', just off to the side of one of the long, bright rays of debris splashed out by the impact that formed Tycho, many hundreds of kilometres to the south. As lunar craters go Bullialdus isn't a giant, but it's no pinprick either. With a diameter of 61 kilometres (38 miles) it is two-thirds the diameter of more famous Copernicus and only a quarter the size of enormous Clavius, but it offers telescope-owning lunar observers a fine sight in eyepieces and can be seen easily through a pair of binoculars, too.



At high magnification Bullialdus resembles Copernicus; it's roughly circular, surrounded by a rampart of material and its walls are steep and broken into many ledges, shelves and terraces. It has a hummocky floor with a striking central peak that is actually a grouping of four individual peaks, giving it the appearance of a four-leaf clover when illuminated from certain angles. High magnification reveals a trio of small impact craters on the crater floor to the north of these peaks, shaped, some think, like the brightest stars of the constellation of Aries.

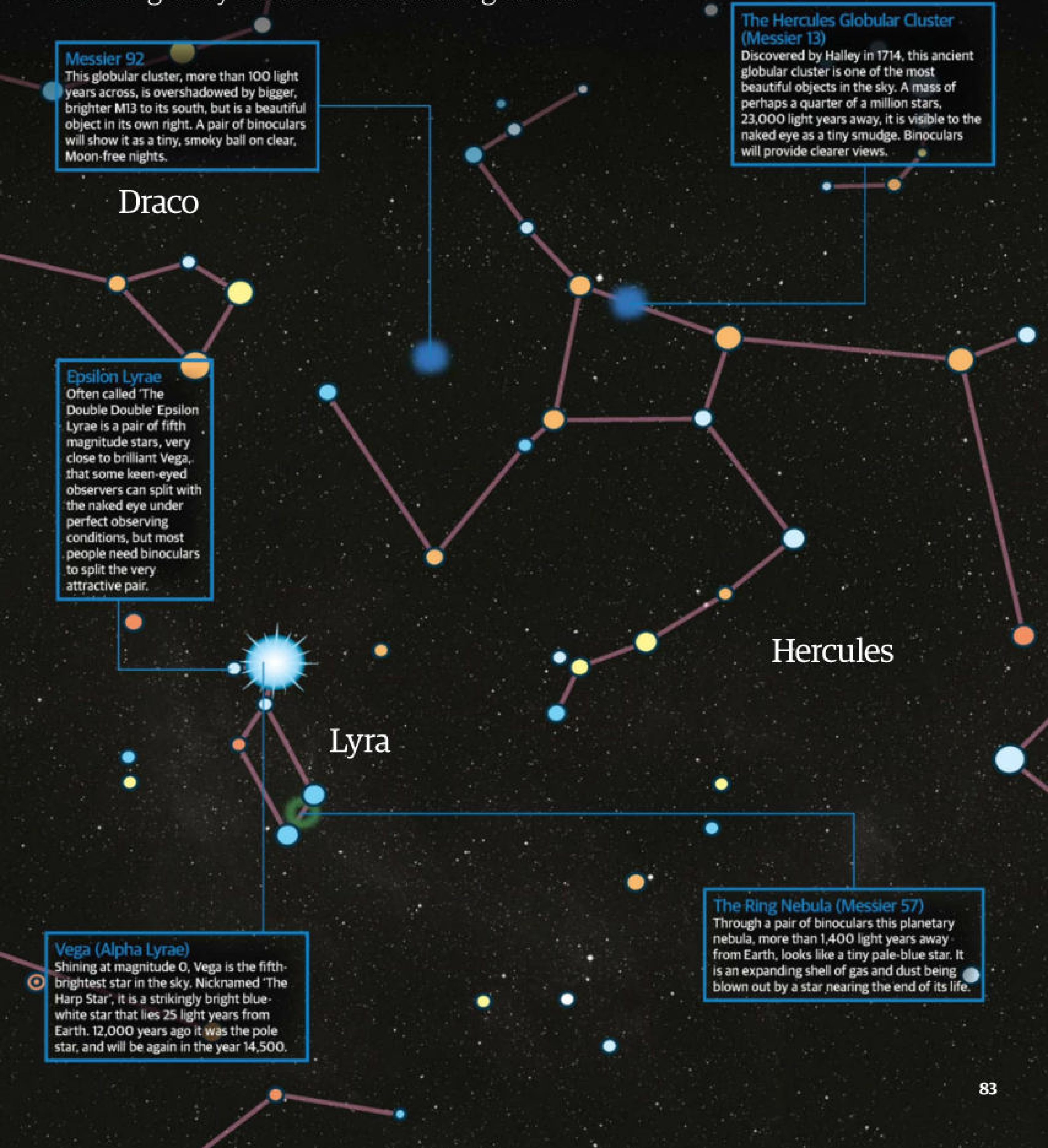
For such a small crater Bullialdus has certainly been in the headlines a lot. In 2010 NASA's Lunar Reconnaissance Orbiter's cameras zoomed in on the summits of its central mountain peaks and took spectacular photos showing them covered with bright piles of boulders, rocks and stones - debris thrown up onto them either by the impact that created the crater or impacts which blasted out craters around it. And in August 2013 NASA's M^3 instrument onboard India's Chandrayaan-1 lunar orbiter discovered water deposits within the crater, locked up in its rocks.

So when can you see this crater for yourself? At the start of our observing period the Moon will be approaching its last-quarter phase, so Bullialdus will be fully illuminated. Through a telescope it will resemble a bright ring with a dark interior and bright central peaks. The terminator will sweep towards it on 28 May, and on that evening it will look very striking in the low sunlight before the terminator crashes over it the following day and it vanishes. We won't see the crater again until 13 June when it will emerge from the lunar night and will again look striking through a telescope. Fully illuminated again on 15 June, the crater will return to looking like a bright coffee-cup-stain ring on the shore of the Sea of Clouds.

© NASA/ James Stub

Naked eye & binocular targets

If you can stay up late enough for it to get dark, June's night sky offers some fascinating treats...



Messier 92
This globular cluster, more than 100 light years across, is overshadowed by bigger, brighter M13 to its south, but is a beautiful object in its own right. A pair of binoculars will show it as a tiny, smoky ball on clear, Moon-free nights.

The Hercules Globular Cluster (Messier 13)
Discovered by Halley in 1714, this ancient globular cluster is one of the most beautiful objects in the sky. A mass of perhaps a quarter of a million stars, 23,000 light years away, it is visible to the naked eye as a tiny smudge. Binoculars will provide clearer views.

Epsilon Lyrae
Often called 'The Double Double' Epsilon Lyrae is a pair of fifth magnitude stars, very close to brilliant Vega, that some keen-eyed observers can split with the naked eye under perfect observing conditions, but most people need binoculars to split the very attractive pair.

Vega (Alpha Lyrae)
Shining at magnitude 0, Vega is the fifth-brightest star in the sky. Nicknamed 'The Harp Star', it is a strikingly bright blue-white star that lies 25 light years from Earth. 12,000 years ago it was the pole star, and will be again in the year 14,500.

The Ring Nebula (Messier 57)
Through a pair of binoculars this planetary nebula, more than 1,400 light years away from Earth, looks like a tiny pale-blue star. It is an expanding shell of gas and dust being blown out by a star nearing the end of its life.

How to...

Photograph a twilight gathering of worlds

When two planets shine close together in the sky it's always a special sight. But when the slim crescent Moon crashes the party in the sky after sunset the result is something truly magical...

You'll need:

- ✓ DSLR camera
- ✓ Standard 50mm or wide-angle lens
- ✓ Sturdy tripod
- ✓ Cable release
- ✓ Photo-processing software

As they wander along the ecliptic, it's inevitable that pairs of planets will sometimes come together, appearing close in the sky. Astronomers call such a celestial close encounter a 'conjunction', and they are one of the easiest and prettiest things a stargazer can see. Such an event might happen several times a year, and amateur astronomers look forward to these because they look so striking.

If both planets involved are bright naked-eye objects, such as Venus and Mars, or Jupiter and Saturn, they can appear like a lovely 'double star' in the sky when they're at their closest. Sometimes pairs of planets appear so close together that they are actually too close for the naked eye to split - then they are best viewed through binoculars or even a small telescope.

Occasionally a crescent Moon will drift into the area of a planetary conjunction too, and then what would have been a special sight becomes something truly spectacular, beautiful enough to stop people in their tracks as they go about their business. This is what will happen on the evening of 5 June, when - if your sky is clear - you'll be able to see Mercury and Mars shining close together in the northwest after sunset with a beautiful fingernail-clipping-thin crescent Moon close by too.

You won't need a telescope to see this grand celestial gathering, as all three of the worlds involved will be clearly visible to the naked eye. However, if you have a pair of binoculars they will really improve your view, making Mars and Mercury look much brighter, and you'll also be able to see the subtle lavender-pink glow of 'Earthshine' on the unilluminated part of the Moon's face.

As attractive as this scene will be visually, it will also be a photographic treat. To capture it you'll need to use a DSLR on a sturdy tripod, and you'll also need a clear view to the northwest, with as flat a horizon as possible. Mercury will be very low in the sky and any trees, buildings or hills in that direction will almost certainly obscure it.

> "One of the easiest and prettiest things a stargazer can see"

Tips & tricks

Find a clear view in advance

Scout out an observing site where you'll be able to see without any obstructions on the horizon.

Be an early bird

Don't wait until the Sun sets to get to your observing site. Be there before sunset so you can catch the Moon and planets shining together as quickly as possible.

Use binoculars

Sweep the northwestern sky with binoculars to find the Moon. The earlier you spot it, the more time you'll have to plan your photos.

Take lots of photos

Once the sky is dark enough to see the Moon, Mars and Mercury, take as many photos as possible. Try different exposure times to be sure some show all three.

Getting the perfect shot

Be in the right place at the right time

A standard 50mm or a wide-angle lens will be fine to photograph the celestial trio. Make sure you focus sharply on the Moon's scimitar-thin crescent, and bracket your exposures to be sure of getting some that show not only the Moon's crescent and the two planets, but the subtle lavender glow of Earthshine on the Moon too. Take plenty of photos to heighten your chance at the perfect shot.

Send your photos to
space@spaceanswers.com

1 **Choose the ideal site**
Find an observing site with a clear view to the northwest and a low horizon. Even low trees, buildings or hills will obscure your view.

2 **Seek out the Moon**
Look for the Moon with binoculars as soon as the sky begins to darken. This will help you to frame your photos as soon as the sky is dark enough.

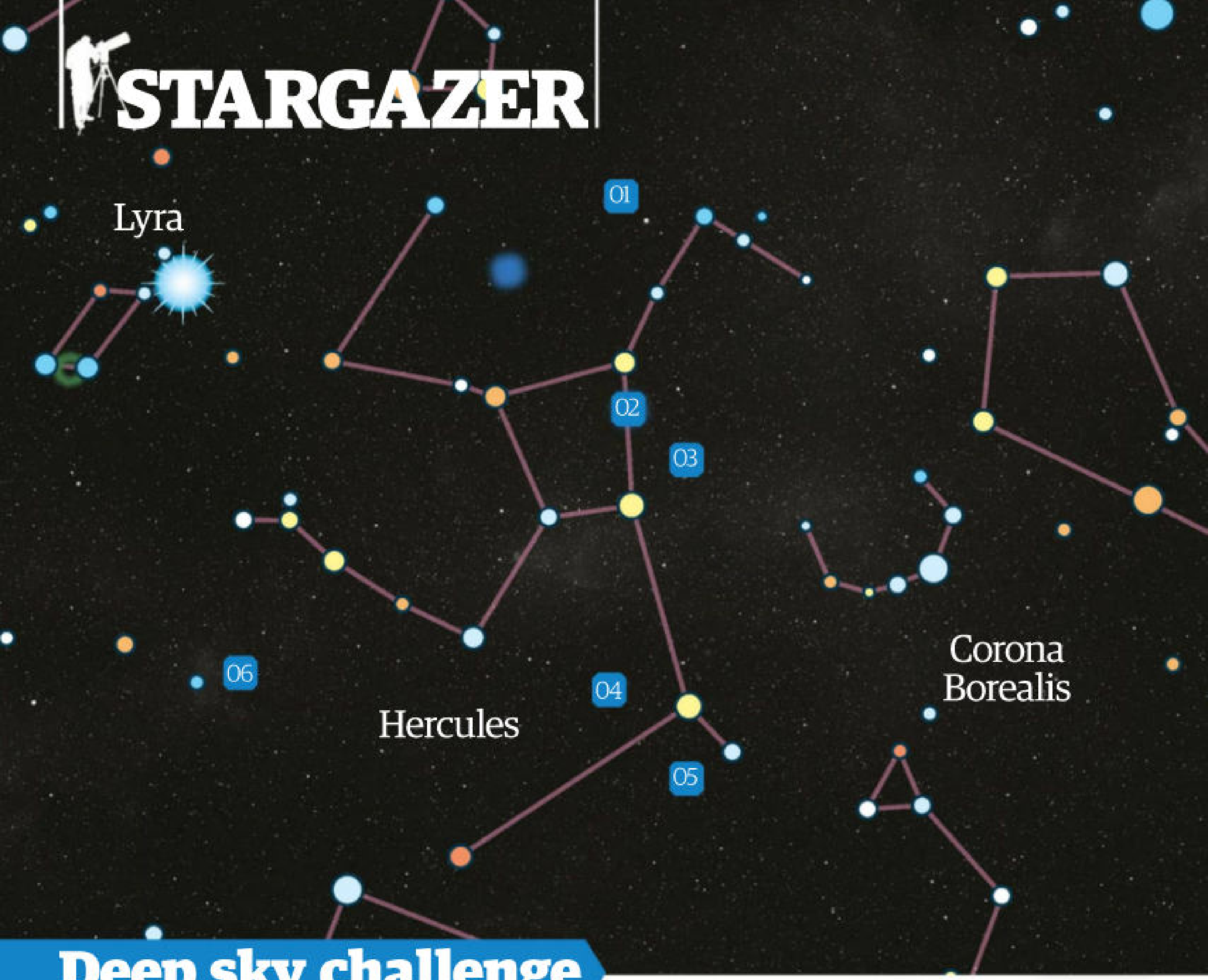
3 **Set up early**
Set up your camera on its tripod and focus sharply on the crescent Moon, even if you can't see Mars or Mercury yet.

4 **Take test shots**
Once Mars and Mercury appear take a variety of test shots using different exposure times and ISO settings.

5 **Take other opportunities**
When the Moon and planets have sunk low in the sky, keep taking photographs to capture the beautiful sunset colours.

6 **Take care with processing**
Be careful to retain the sky's natural colours. Don't push the contrast and saturation levels too far.

©Mike Lewinski



Deep sky challenge

Hidden wonders of Hercules the Hero

There's more to this constellation than M13, the most beautiful globular cluster in the northern sky

Think of the constellation of Hercules and naturally you think of M13, the Hercules Globular Cluster. Many observers think it is the finest globular cluster in the northern sky, and that's fair enough. It can be seen with the naked eye on a clear, Moon-free night – just – and contains perhaps a million stars all packed closely together. The problem is it is so impressive it tends to hog the Herculean limelight and overshadows everything else in that constellation. There's another problem: by the time June rolls around the night sky doesn't actually get dark for those at mid-northern latitudes until well after midnight, so if you want to see any of these underappreciated objects you'll need to stay up late or set your alarm for early in the morning.

Unsurprisingly this part of the sky, away from the glittering star clouds of the Milky Way, is poor in gaseous nebulae but rich in clusters and galaxies. All are very distant and faint, so small in even high-power eyepieces, but the satisfaction you'll get from tracking them down makes up for their rather underwhelming visual appearance!

NGC 6207

NGC 6210

1 NGC 6229

This ninth-magnitude globular cluster is no rival for M13, but it can be resolved at high magnifications into a small, smoky ball.

2 NGC 6207

Roughly 50 million light years away but just half a degree away from M13, in a large telescope's high-power eyepiece the 11th-magnitude galaxy is a small elongated smudge.

3 NGC 6916

You'll only see hints of this 14th-magnitude spiral galaxy's tightly wound arms through a large telescope under a perfectly clear and dark sky. It is an amazing 460 million light years away.

4 NGC 6210

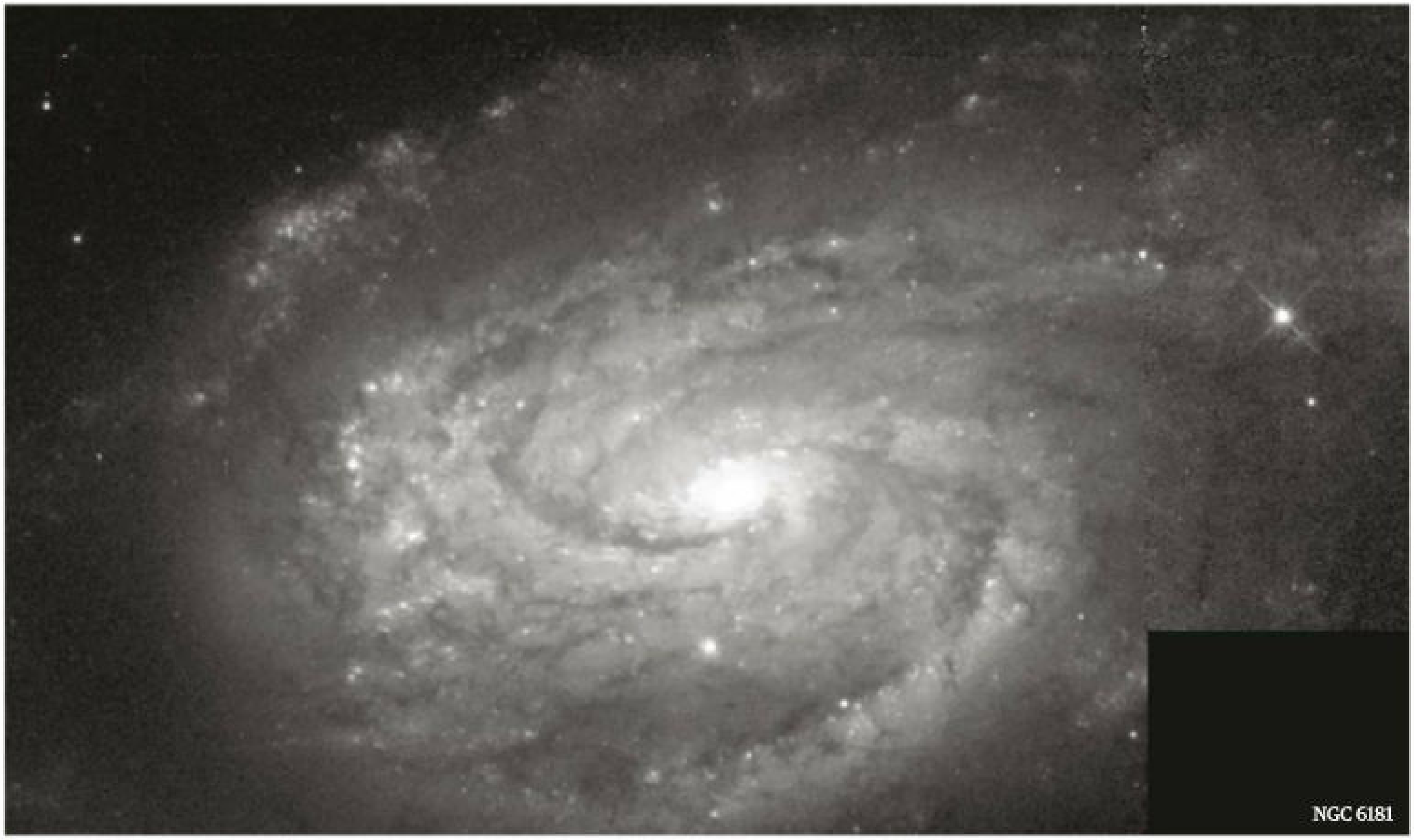
This magnitude 8.8 planetary nebula's smoky ring can be seen through small telescopes, but with an 8" or larger instrument you'll see hints of blue and green colour and the star at its centre.

5 NGC 6181

This tightly wound spiral galaxy lies 110 million light years from Earth. Magnitude 11.6, you'll need a large telescope, a dark sky and high magnification to resolve its sweeping spiral arms.

6 NGC 6482

This elliptical galaxy is over 200 million light years away. At 11th magnitude and, like all ellipticals, it will just look like a faint smudged oval in any telescope, no matter how large its aperture is.


NGC 6181

© Wil Tirion; ESA/Hubble and NASA; Fabian RRRR;

The Northern Hemisphere

Those longing for a wide variety of targets to track down won't be disappointed – despite lighter nights

This June all you need is the naked eye to spot some of the exquisite close approaches between the Moon and a selection of planets in our Solar System – most notably Jupiter and Venus swinging by our natural satellite during various times of the month. The King of the Solar System also heads for opposition on 10 June, offering itself as an excellent target for those wanting to observe its surface detail or its largest Galilean moons – Io, Europa, Ganymede and Callisto – with binoculars or a telescope.

If you're keen to get stuck into observing nebulae, galaxies and star clusters you will find that there's a modest amount of these targets to get your teeth into, too, despite the lighter nights.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

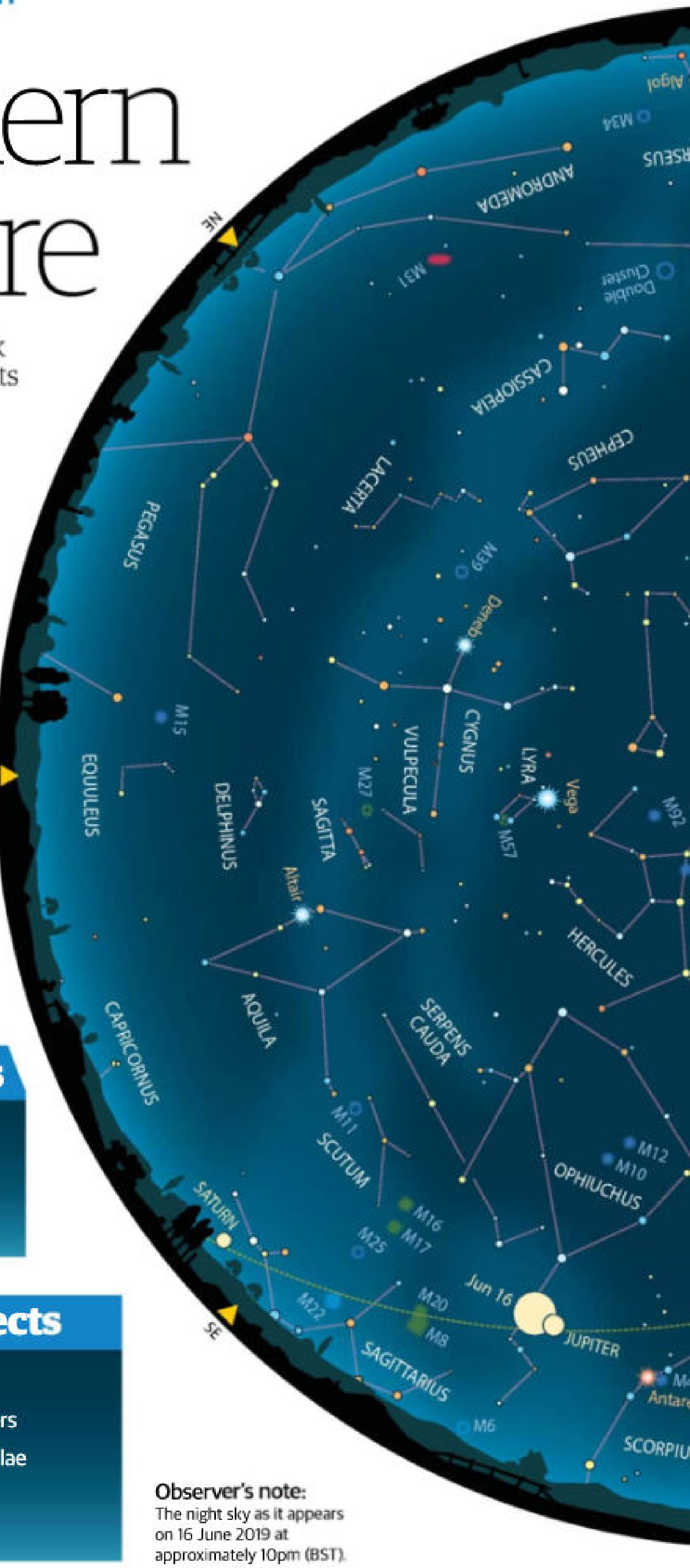
- ✸ Sirius (-1.4)
- ✸ -0.5 to 0.0
- ✸ 0.0 to 0.5
- ✸ 0.5 to 1.0
- ✸ 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ○ Variable star

Spectral types

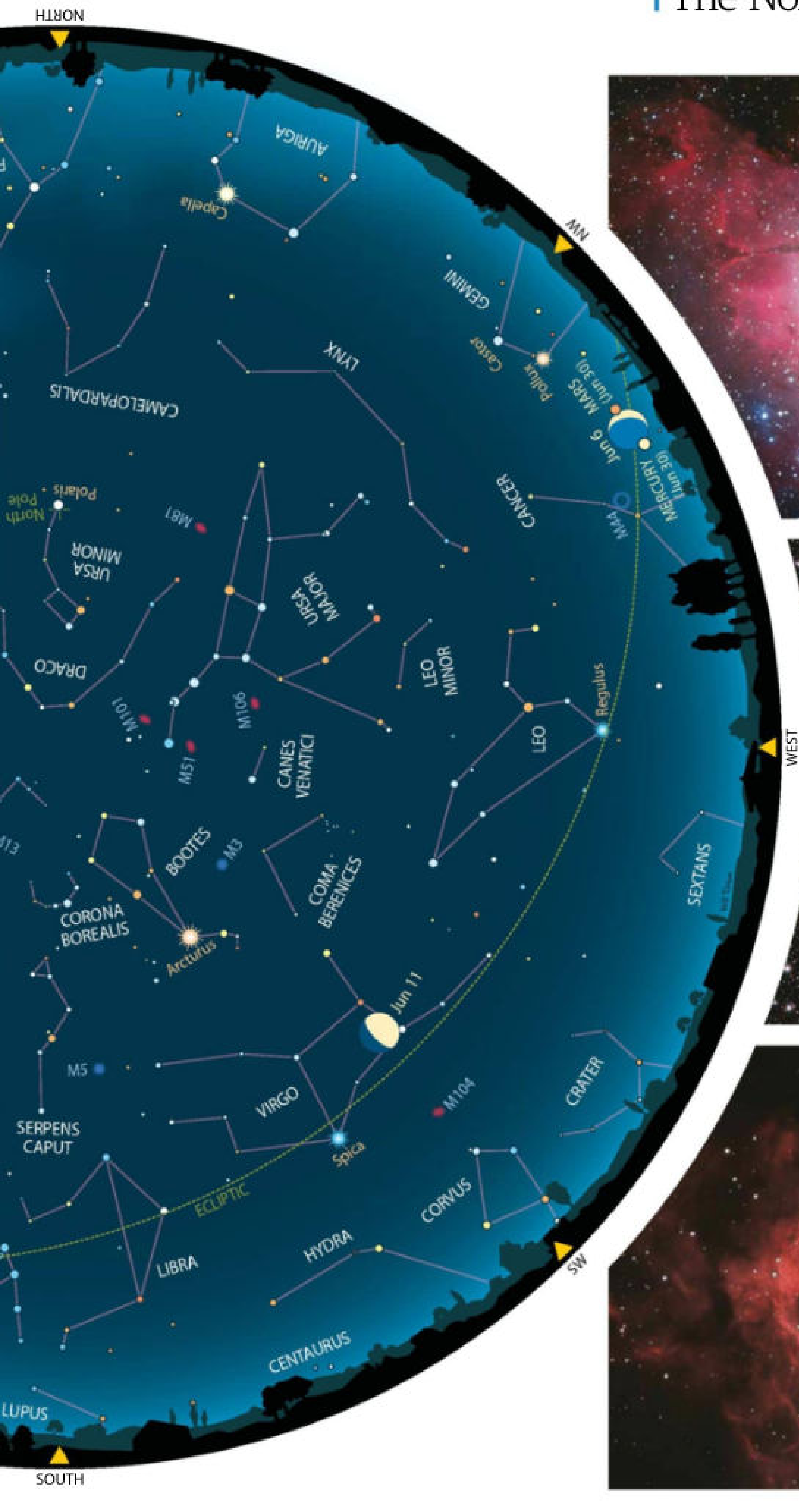
- ✸ ● O-B
- ✸ ● A
- ✸ ● F
- ✸ ● G
- ✸ ● K
- ✸ ● M

Deep-sky objects

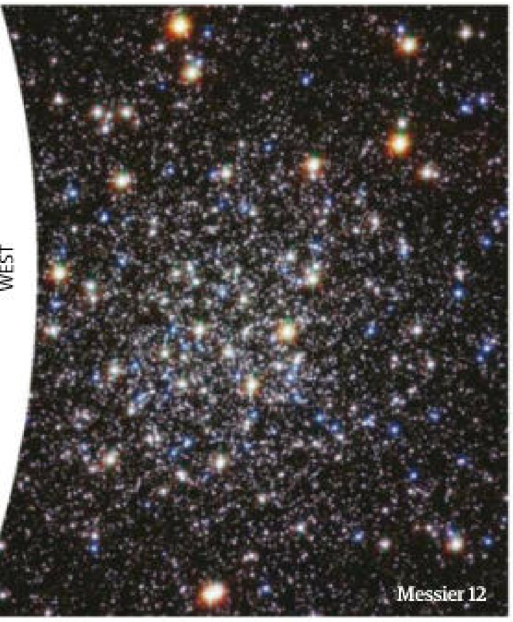
- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies



Observer's note:
The night sky as it appears on 16 June 2019 at approximately 10pm (BST).



Eagle Nebula (Messier 16)

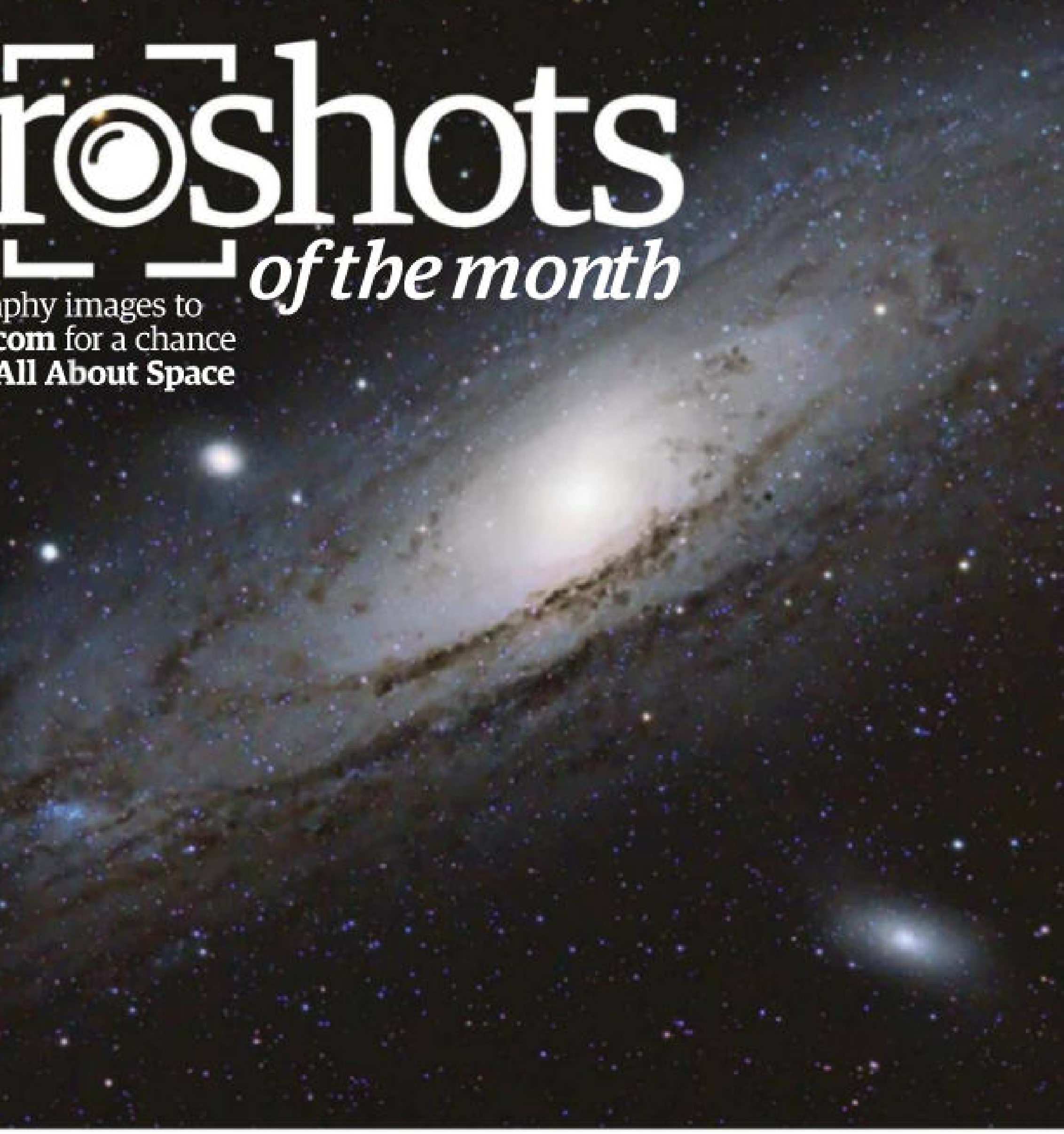

Messier 12

Omega Nebula (Messier 17)

© Wil Tirion; ESA/Hubble & NASA; ESO; Chuck Ayoub

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



Trevor Jones

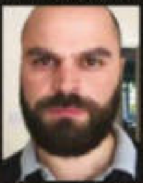
Ontario, Canada

Telescope: Explore Scientific ED80 refractor

"I have enjoyed many beautiful nights under the stars over the past six years. After joining the local astronomy club in my area, RASC Niagara, I learnt a lot about astrophotography in a short period of time. Whenever possible, I like to set up my telescope and take images of deep-sky objects to share on my astroimaging blog.

"My shot of the Andromeda Galaxy, also designated Messier 31, is one of my favourite images to date. I took this image at the CCCA Observatory in Wellandport, Ontario, under exceptionally clear skies – it combines over three hours worth of four-minute exposures with a Canon 450D DSLR camera."

Chris Grimmer



Norwich, UK

Telescope: Celestron C9.25 and William Optics GT-81 refractor

"My route into astrophotography started a couple of years back when, one night in my local pub, I discovered that the landlord's son owned a telescope. So, in the early hours of the morning, we headed outside to the car park to observe the night sky.

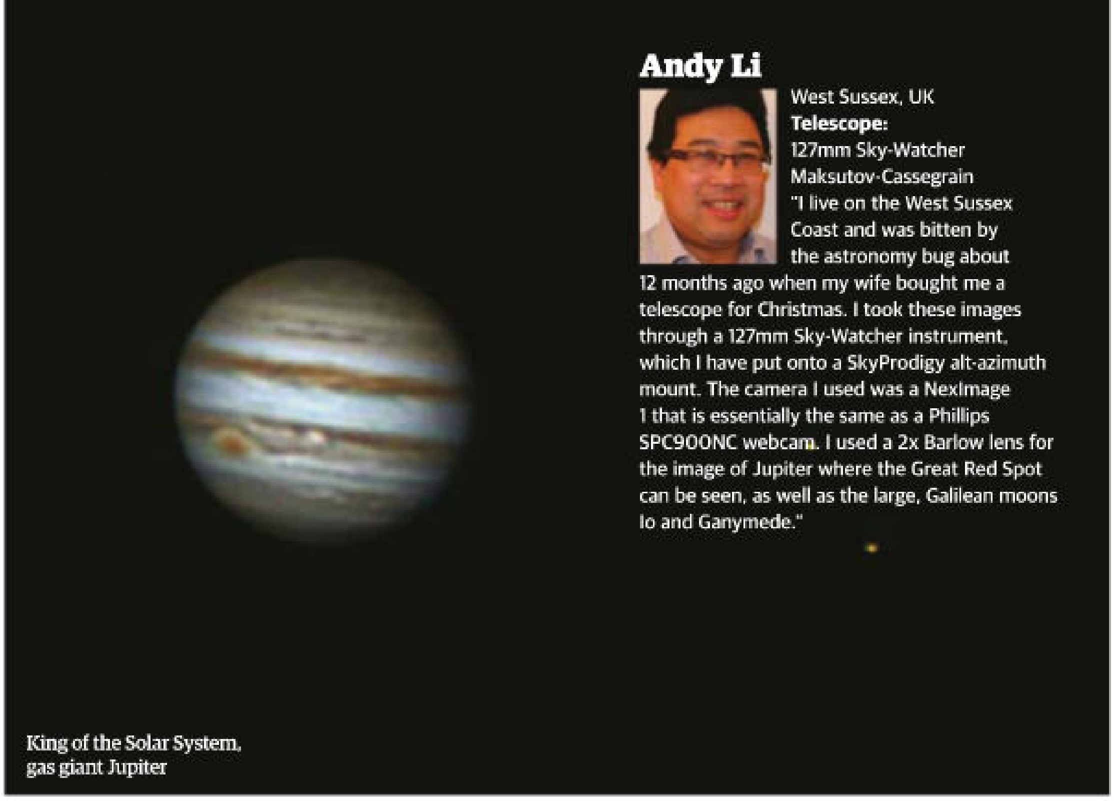
"I soon paid a visit to my local astronomical society and, the following day, bought my first 'scope. I have always been interested in photography, so it wasn't long before I had modified a cheap webcam and achieved my first image of Jupiter. It was then that the astronomy bug really hit. From that point onwards my kit became rapidly upgraded, to the point where not a month passed without something new being delivered to me."

Andy Li

West Sussex, UK

Telescope: 127mm Sky-Watcher Maksutov-Cassegrain

"I live on the West Sussex Coast and was bitten by the astronomy bug about 12 months ago when my wife bought me a telescope for Christmas. I took these images through a 127mm Sky-Watcher instrument, which I have put onto a SkyProdigy alt-azimuth mount. The camera I used was a NexImage 1 that is essentially the same as a Phillips SPC900NC webcam. I used a 2x Barlow lens for the image of Jupiter where the Great Red Spot can be seen, as well as the large, Galilean moons Io and Ganymede."



King of the Solar System, gas giant Jupiter

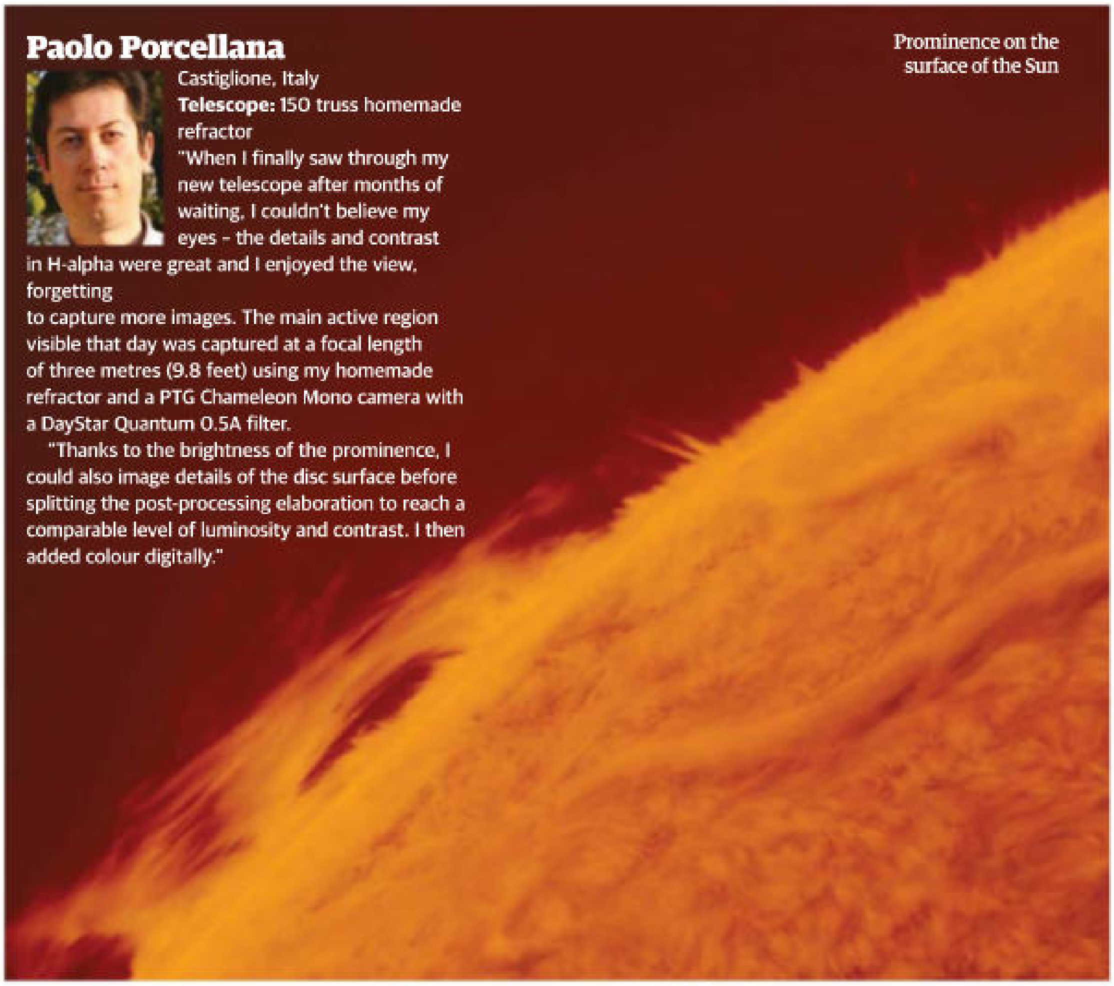
Paolo Porcellana

Castiglione, Italy

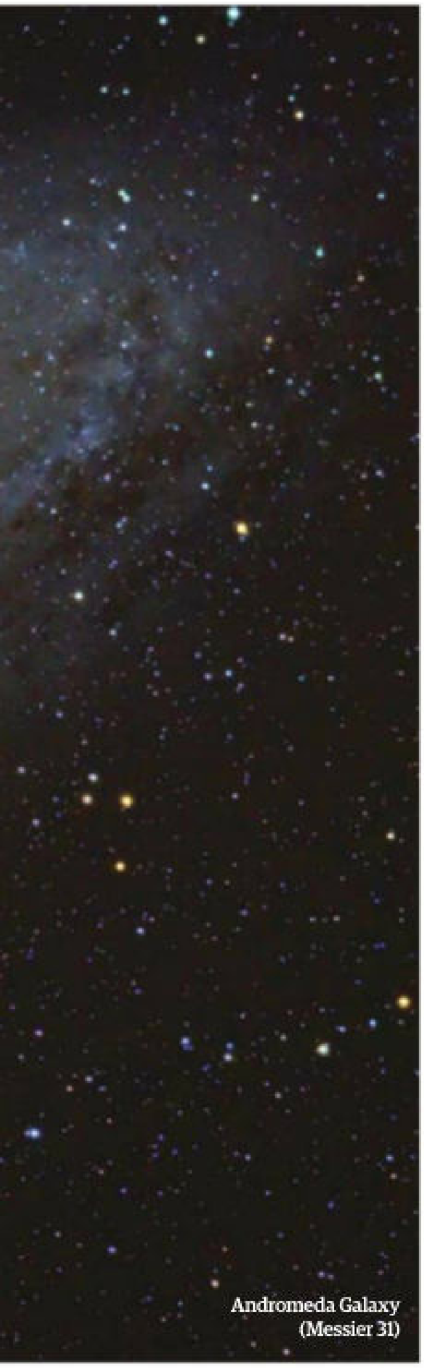
Telescope: 150 truss homemade refractor

"When I finally saw through my new telescope after months of waiting, I couldn't believe my eyes – the details and contrast in H-alpha were great and I enjoyed the view, forgetting to capture more images. The main active region visible that day was captured at a focal length of three metres (9.8 feet) using my homemade refractor and a PTG Chameleon Mono camera with a DayStar Quantum 0.5A filter.

"Thanks to the brightness of the prominence, I could also image details of the disc surface before splitting the post-processing elaboration to reach a comparable level of luminosity and contrast. I then added colour digitally."



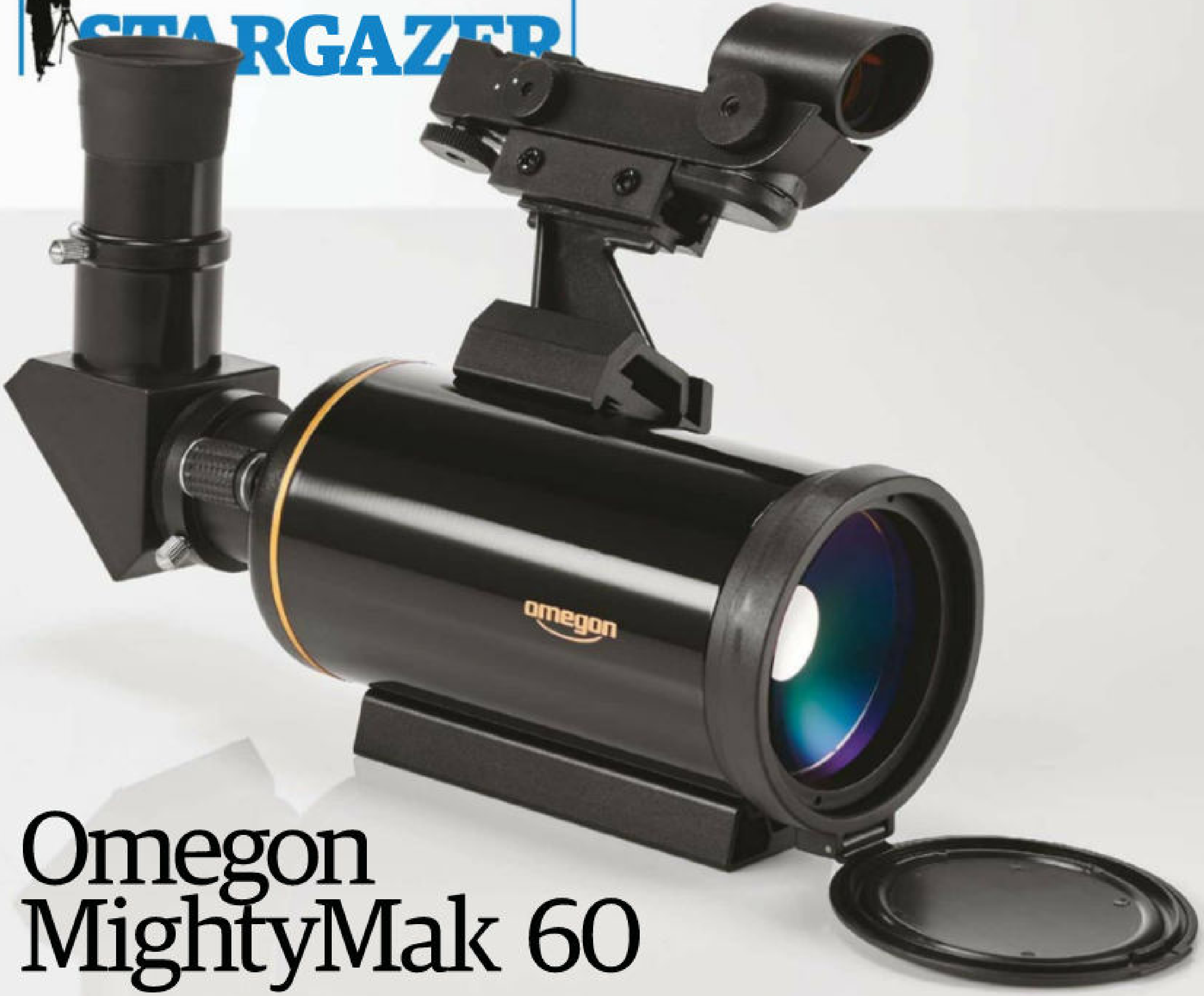
Prominence on the surface of the Sun



Andromeda Galaxy (Messier 31)

Veil Nebula (NGC 6960)

Send your photos to... @spaceanswers @ space@spaceanswers.com



Above: The MightyMak 60 is suitable for afocal photography or basic astrophotography with an appropriate adapter

Omegon MightyMak 60

Highly portable, simple to use and ideal for beginners on a budget, this small telescope is an excellent introduction to astronomy

Telescope advice

Cost: £86 ($111.95)
From: astroshop.eu
Type: Maksutov-Cassegrain
Aperture: 2.36"
Focal length: 27.56"

Left: The MightyMak 60 is supplied with a red dot finder to assist with navigation

If you're looking for a telescope that's easy to carry and set up for your very first venture into observing, or if you have children that have been hassling you for a telescope but you don't want to spend a fortune on a 'scope for a hobby that could end up being a fad, then the Omegon MightyMak 60 is a worthwhile option to consider.

For a low price, manufacturer Omegon provides two types of mount, a table tripod and a Dobsonian, ideal for quick night-sky viewing, a Kellner 25mm eyepiece and a handy, sleek transport bag. Unusually, however, there didn't seem to be a finderscope or red dot finder to assist with finding objects, something that may hinder a novice astronomer's observing sessions to a large degree. For the purpose of this review, we attached an in-house red dot finder to the telescope in order to test it sufficiently. Overall the MightyMak 60 is very well built, and the tube in particular is of superb quality. The build of the table-top tripod doesn't seem to support the tube well without severely tightening the pan handle. The MightyMak 60 is sufficiently packaged in bubble wrap to ensure safe transportation. The flip-flop dust cap is a nice touch and fixed to the telescope's objective lens. However, while it ensures that you don't lose this important accessory, we can see that it can be a hindrance while observing - particularly on a windy evenings.

We selected the sturdier Dobsonian mount for our observations. Setting up was a breeze and within moments we got stuck into targeting a selection of objects. With its small aperture, the MightyMak 60 is only really suitable for observing Solar System targets and the surface of the Moon - highly recommended targets for those just breaking into observing the night sky. Slewing from one region of the sky to the other, we enjoyed the smooth operation, while it still gives just the right amount of resistance for stability when observing chosen targets. With Saturn and Mars recently

Left: The tabletop telescope comes with a single 1.25" Kellner 25mm

Below: The tube didn't feel sufficiently supported by the 'wildlife watching' tripod

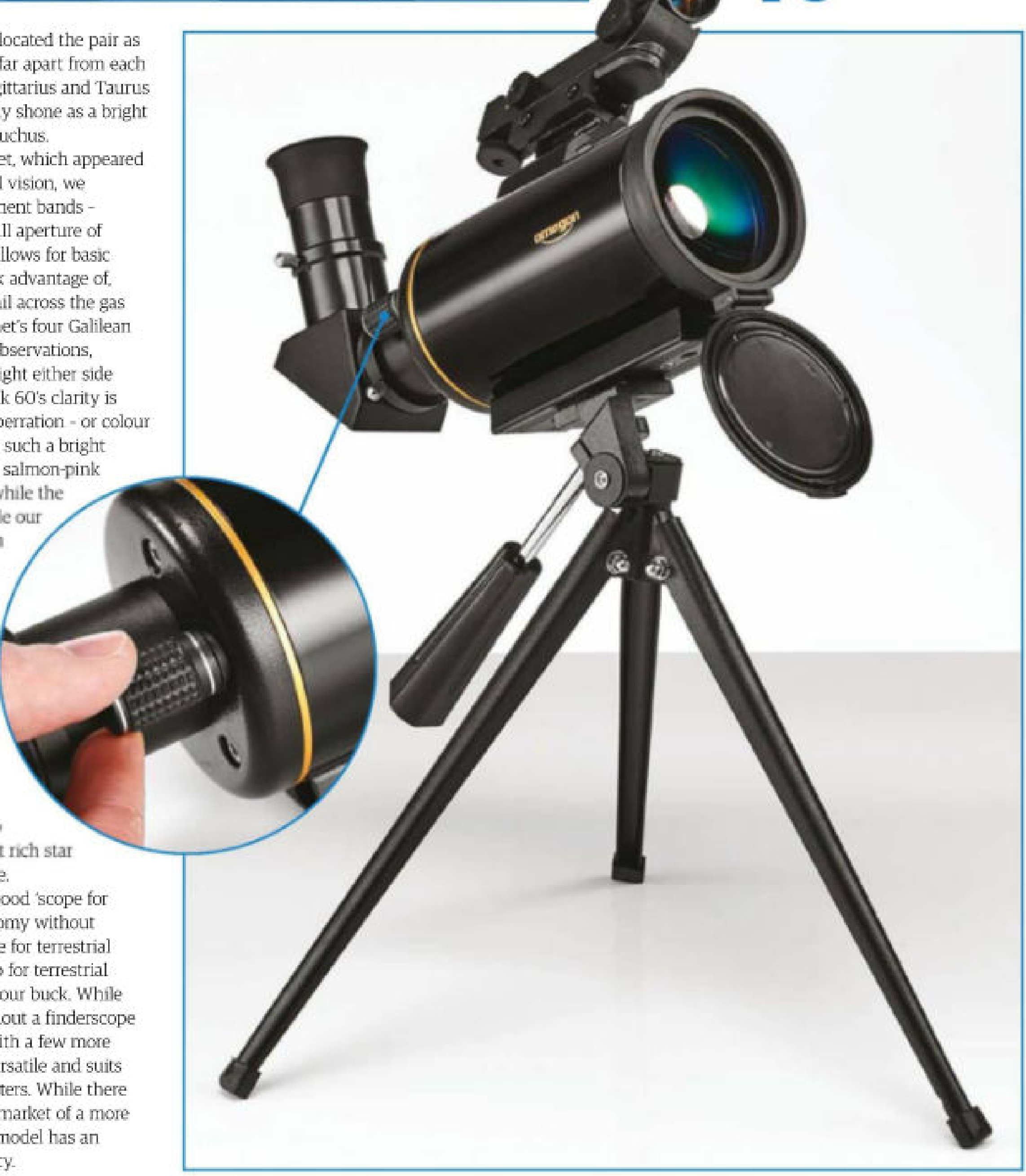
Best for...

- ? Beginners
- £ Small budget
- Planetary viewing
- Lunar viewing
- Terrestrial viewing
- Basic astrophotography

reaching opposition, we quickly located the pair as yellowish and red 'stars' not too far apart from each other in the constellations of Sagittarius and Taurus respectively, while Jupiter proudly shone as a bright 'star' in the constellation of Ophiuchus.

We made Jupiter our first target, which appeared as a bright disc. By using averted vision, we could make out two of its prominent bands – an impressive feat given the small aperture of this 'scope. The MightyMak 60 allows for basic astrophotography, which we took advantage of, revealing much more subtle detail across the gas giant's equator. Three of the planet's four Galilean moons were visible during our observations, appearing as lined-up points of light either side of Jupiter's limbs. The MightyMak 60's clarity is impressive, with no chromatic aberration – or colour fringing – visible on the edges of such a bright object. Mars appeared as a small salmon-pink disc over the southern horizon while the ringed giant stole the show. While our views of the planet were small in the field of view, we were blown away by the planet's majestic rings. While conditions weren't favourable enough to pick out the Cassini Division without the aid of photography equipment, the MightyMak 60 surpassed expectations. The manual states that the 'scope isn't very useful in observing deep-sky objects. While on the whole this is true of this desktop 'scope, it is capable of picking out rich star clusters, as well as bright nebulae.

The MightyMak 60 is a very good 'scope for those wanting to get into astronomy without breaking the bank. Being suitable for terrestrial views, the 'scope also doubles up for terrestrial viewing, adding more bang for your buck. While the set-up came incomplete without a finderscope and could have been supplied with a few more accessories, the MightyMak is versatile and suits a wide range of eyepieces and filters. While there are cheaper instruments on the market of a more substantial size, this 'pint-sized' model has an advantage thanks to its portability.



WIN

OMEGON MIGHTYMAK 60 TELESCOPE AND *AN ASTRONOMER'S TALE*

On offer is a powerpack telescope, as well as the story of a stargazer's journey

The MightyMak 60 is a compact piece of kit that offers impressive magnification power. This Maksutov-Cassegrain instrument is capable of observing nature and animals, as well as the night sky. Its aperture size of 60 millimetres (2.4 inches) and ratio of f/11.7 means it's great for not only observing, but also photographing both nature and night-sky objects such as the Moon, planets and bright stars.

Along with the MightyMak we're also giving away *An Astronomer's Tale: A Bricklayer's Guide to the Galaxy*, by Gary Fildes. This entertaining read contains the memoirs of how Fildes went from a bricklayer to the founder of his own observatory, the Kielder Observatory in Northumberland. While you wait for dark skies to reveal a plethora of Solar System and deep-sky targets, dip into the inspiring astronomical story in the meantime.

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18 June saw which NASA lunar spacecraft launch from Earth ten years ago?

A: ARTEMIS

B: LADEE 2

C: Lunar Reconnaissance Orbiter

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Congratulations to Tom Garwood, who is the winner of the Sky-Watcher StarTravel-102 telescope!

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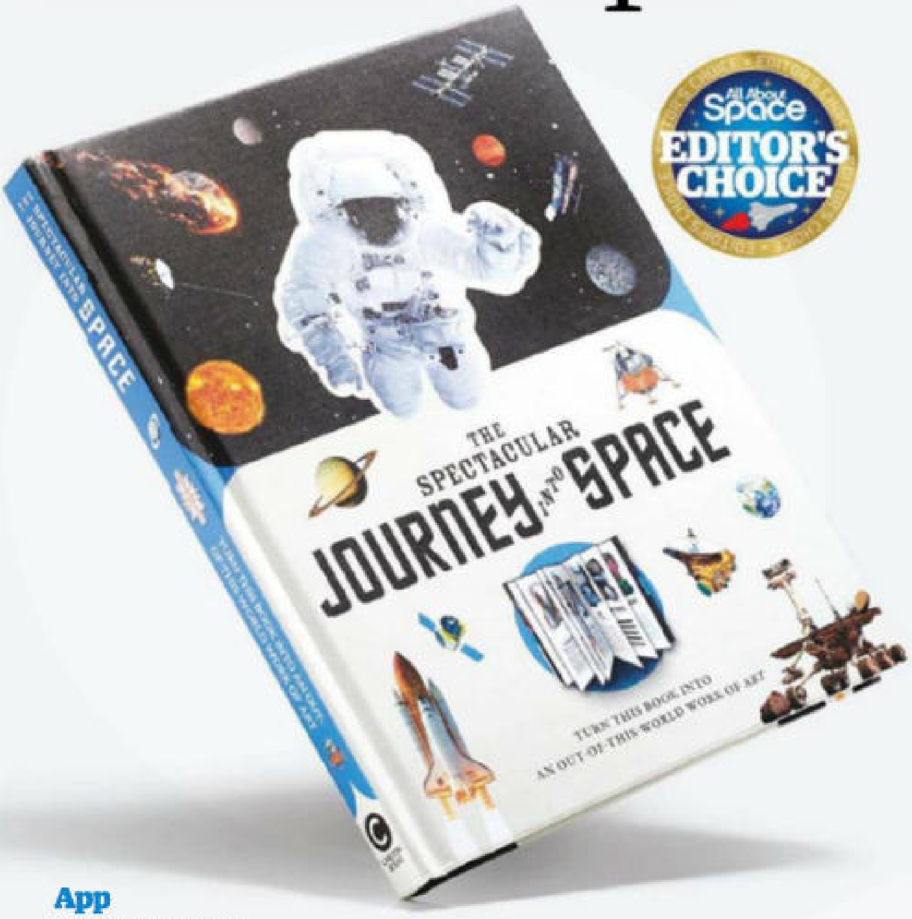

All About Space
EDITOR'S CHOICE
THE SPECTACULAR JOURNEY INTO SPACE
TURN THIS BOOK INTO AN OUT-OF-THIS-WORLD WORK OF ART

Book

Paperscapes: The Spectacular Journey into Space

Cost: £12.99
From: Carlton Books

The Spectacular Journey into Space certainly is just that as it delves into the natural wonders found in the universe, featuring the brilliant objects and machines that have gone - and will go - into space. The unique die-cut format lets the stunning photos leap off the page, forming a gallery of everything from stars and rovers to telescopes and probes. From the Space Shuttle to the Space Launch System, there's something new to discover with every turn of the page. The pages are double-sided, beginning with the Sun before gradually moving through the planets of the Solar System, and featuring the International Space Station along with a variety of space corporations and missions.

While this book will be adored by anyone who is enthusiastic about space, the book would certainly be appreciated by the young who are new to learning about the universe. Thanks to the die-cut pages that allow you to pop out sections, turning the book into a work of art, you can truly discover space as you've never seen it before.

App

Cosmic Watch

Cost: £3.99
From: iTunes

Cosmic Watch is a 3D planetarium, an AR sky guide and a clock. This powerful educational tool renders stunning graphics of the Earth and sky in real time. It's a playful introduction to astronomy.

Take an astronaut's flight over planet Earth or explore the entire Solar System. Point your phone or tablet towards the sky and experience it in augmented reality. Get to know the constellations, stars and planets in your sky right now! Travel to the past, present and future and see how time is related to the movements of the Solar System.

Cosmic Watch combines basic principles of astronomy with time measurement to deliver a journey through space and time while providing real-time visualisations of your position in the cosmos. *Cosmic Watch* 2.0 calculates important astronomical events so you never miss the next cosmic phenomena.

Cosmic Watch is for everyone who loves the planet Earth or wishes to unlock the secrets of the celestial vault. It's a must-have for nature lovers and outdoor adventures, amateur astronomers and advanced stargazers.

Software
Space Engine

Cost: Free
From: spaceengine.org

SpaceEngine is a realistic virtual universe you can explore on your computer; a proprietary 3D astronomy program and game engine developed by Russian astronomer and programmer Vladimir Romanyuk. It creates a 3D planetarium of the entire universe from a combination of real astronomical data and scientifically accurate algorithms.

You can travel from star to star, from galaxy to galaxy, landing on any planet, moon, or asteroid with the ability to explore its alien landscape. You can alter the speed of time and observe any celestial phenomena you please. All transitions are completely seamless, and this virtual universe has a size of billions of light years across. The procedural generation is based on real scientific knowledge, so *SpaceEngine* depicts the universe the way it is thought to be by modern science. Real celestial objects are also present to explore, including the planets and moons of our Solar System.

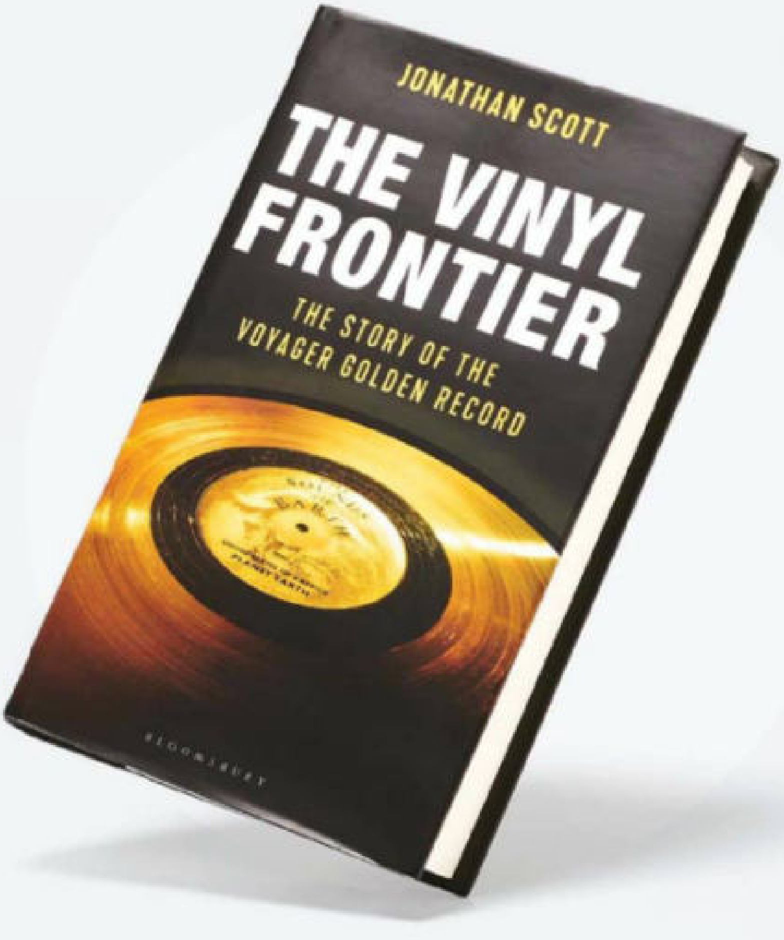
> "It creates a 3D planetarium of the entire universe from real data"

Book
The Vinyl Frontier: The Story of the Voyager Golden Record

Cost: £16.99
From: Bloomsbury Sigma

The Vinyl Frontier tells the story of NASA's interstellar mixtape, from the first phone call to Voyager 1 and 2 leaving our planet bearing their hopeful message from the summer of 1977. *The Vinyl Frontier* explains how the record was created, from when NASA first proposed the idea to Carl Sagan to when it was finally able to watch the Golden Record rocket off into space on Voyager, carrying music composed by Bach, Beethoven and Chuck Berry as well from China, India and more remote cultures such as a community in Small Malaita in the Solomon Islands. It also contained a message of peace from US president Jimmy Carter, a variety of scientific figures and dimensions and instructions on how to use it for a variety of alien life forms. Each song, sound and picture that made the final cut onto the record has a story to tell.

Through interviews with all of the key players involved in its creation, this book pieces together the whole story of the Golden Record. It contains many other fascinating insights that have never been reported before.



HEROES OF SPACE

Valery Bykovsky

He was one of the first generation of cosmonauts, totalling over 20 days in space

27 March 2019 saw the loss of the influential Soviet Union cosmonaut Valery Bykovsky at the age of 84. His contributions to the Soviet space programme at the pinnacle of the Space Race era paved the way for future generations. He still holds the record for the longest solo spaceflight, 56 years after the mission.

Bykovsky was born on 2 August 1934 in Pavlovsky Posad, a town near Moscow in what is now Russia but was formerly the Soviet Union. His family had to move around a lot due to the outbreak of World War II. Pursuing a career as a pilot, in November 1955 he graduated from Kachinsk Military Aviation Academy with outstanding marks in flying and combat training. This began his aviation adventure.

It wasn't until he was 26 years old that he began cosmonaut training. He was selected to be part of the first crop of cosmonauts in March 1960 alongside Yuri Gagarin and was assigned to Vostok 5. He piloted Vostok 5 when it was launched on 14 June 1963. He was the Soviet's fifth person in space and the 11th overall. He spent his time conducting science experiments, photographing Earth's beautiful horizon and recording his body's reaction to the microgravity felt at low-Earth orbit.

After two days in space and 31 orbits around our home planet, Bykovsky was joined by fellow cosmonaut Valentina Tereshkova, who was piloting Vostok 6. They flew in tandem and came as close as five kilometres (three miles) to each other. This spaceflight was designed to last for eight days, but due to powerful and unpredictable solar flare activity – which could have had potentially dire consequences for spacecraft electronics – the mission was ended after four days, 23 hours and seven minutes. This mission holds the record for the longest solo spaceflight in history, but Bykovsky did not stop there.

His next spaceflight came 13 years later as part of the Soyuz 22 mission. Prior to that he was supposed to be commander of the Soyuz 2 mission, but due to several problems during Soyuz 1's flight the mission returned early and there was no need for Soyuz 2 to launch to perform the planned rendezvous. After that he trained for the Soviet's Moon landing programme, but that was scrapped after the United States beat them to it with the Apollo 11 mission.

In September 1976 Bykovsky flew with fellow cosmonaut Vladimir Aksyonov on Soyuz 22. Two years later he saw his third and final orbital flight when he docked onto the Salyut 6 space station as part of the Soyuz 31 mission along with the East German Sigmund Jähn.

Unfortunately his death leaves only two cosmonauts from the original group of 20: Alexei Leonov and Boris Volynov. His contributions to space travel did not go unnoticed as he was named Hero of the Soviet Union and awarded the Order of Lenin and the Order of Red Star – two incredibly prestigious awards – for his efforts.

Bykovsky was the 11th person to fly in space

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> "He was selected to be part of the first crop of cosmonauts in March 1960 alongside Yuri Gagarin"

All About Space

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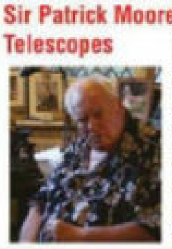

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